ACCUMULATING MECHANISMS

An accumulator, by definition, is a device which is capable of performing the functions of arithmetic. In IBM, it is a common practice to refer to the individual mechanisms which make up an accumulator as counters. A counter is a device which is capable of addition. An example of a simple counter is the device which is sometimes used by a doorman at a public function, such as a play or sports event, when it is desirable to know the number of persons attending. This is a mechanical device that has a button or lever for the doorman to press. Each time he presses the button (which he will do for each person entering), it adds a one, or counts one. This type of counter will only add a one, and consequently to add a six, one must be added six times.

There are many different types of counters, operating on mechanical, electro-mechanical, electrical or electronic principles. IBM uses counters in each of these categories. However, some are in limited use because IBM counters must generally:

1. Accept an electrical impulse
2. Add digit values
3. Carry
4. Indicate the algebraic sign of the number
5. Read-out the result
6. Reset to a zero value

Principles of Addition

Many counters use a wheel to record and accumulate digit values. The number in the counter is represented by the position of the wheel in relation to a fixed reference point. Because our numbering system is based on ten, the wheel can be divided into ten equal parts, or some multiple of ten. Assume a wheel divided into ten parts, as shown in Figure 139. This will be referred to as an add wheel. To add the number four into the counter, it is necessary to rotate the add wheel 4/10 of a revolution. If the counter was previously at the zero position, its new position would represent a four. However, if it had contained a number from a previous operation; such as a two, it would now be in the position representing the sum of the two digits, six. The add wheel is designed to advance one position for every unit to be added.

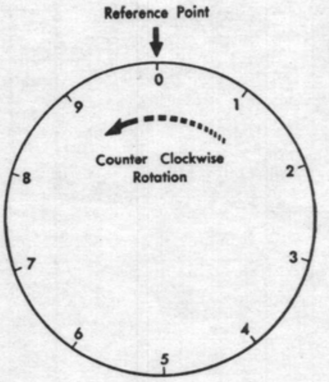


Figure 139. Add Wheel

If the number eight is placed in a counter and the number six is added to it, the sum, of course, is 14. When this operation is done manually, it is necessary to carry into the tens position from the units position. In a manual operation anytime the sum in one position is equal to, or greater than ten, the person adding must remember to carry into the next higher order position. It is also necessary for the machine to remember to carry. Considering the add wheel again, and assuming it has previously accumulated a value of eight, a six is added to it. The add wheel will advance six positions. As a result, the add wheel will move from the eight position through the nine, zero, one, two and three to the four position where it will stop. The units position now contains a four, which is correct. However, the tens counter must be instructed to add one as a result of a carry operation.

Mechanical Principles — Type 402 Counter

Before continuing the study of counter operation, a study of the counter plate, shown in Figure 140, should be made. This figure indicates the names and function of the parts which cause the counter to operate. The counter plate shown is the 402 type which has two complete counters mounted on it. The driven gear is meshed with and driven by a gear which is continuously running during the time the machine is operating. As a result, the adding wheel clutch gear and carry cam are turning continuously. The driven gear, carry cam and adding wheel clutch gear make one revolution per machine cycle.

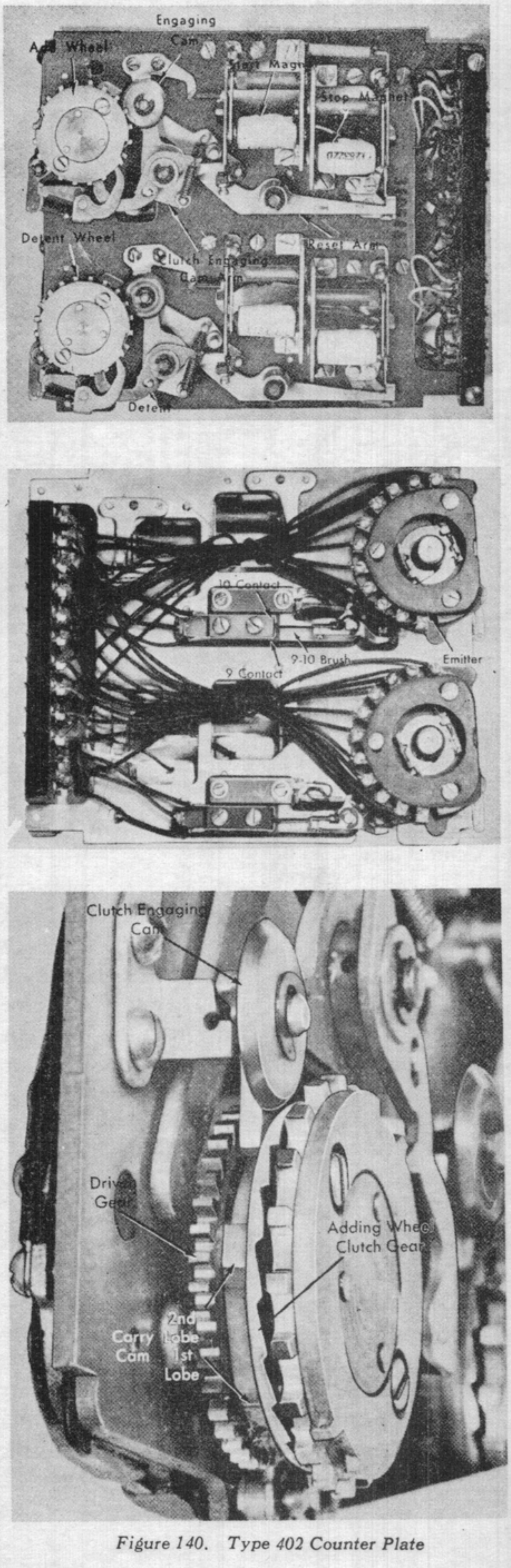


Figure 140. Type 402 Counter Plate

Counter Start

To start the adding wheel it is necessary to engage the clutch by energizing the start magnet. When the start magnet is energized, the armature is pulled away from the clutch engaging cam arm. This permits the clutch engaging cam arm to rotate under spring tension, and move the clutch engaging cam down against the adding wheel clutch gear. The adding wheel clutch gear, being free to slide on its shaft, is pressed in against the adding gear as seen in Figure 141. As the adding wheel clutch gear continues to turn, it meshes the clutch teeth and the adding wheel begins to turn.

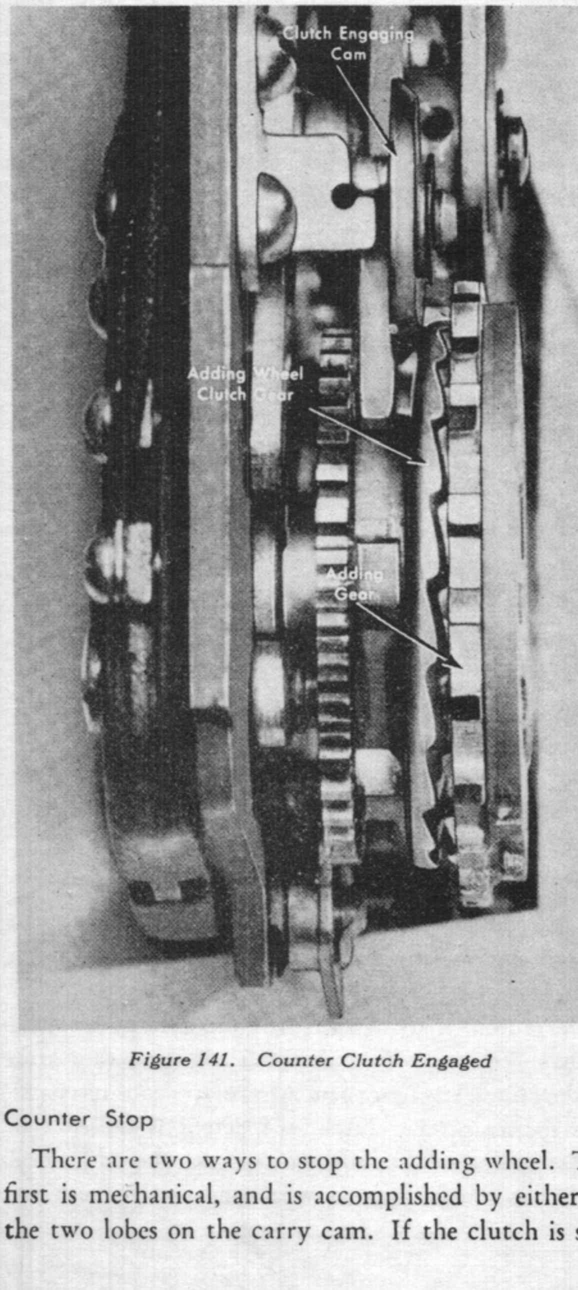


Figure 141. Counter Clutch Engaged

Counter Stop

There are two ways to stop the adding wheel. The first is mechanical, and is accomplished by either of the two lobes on the carry cam. If the clutch is still

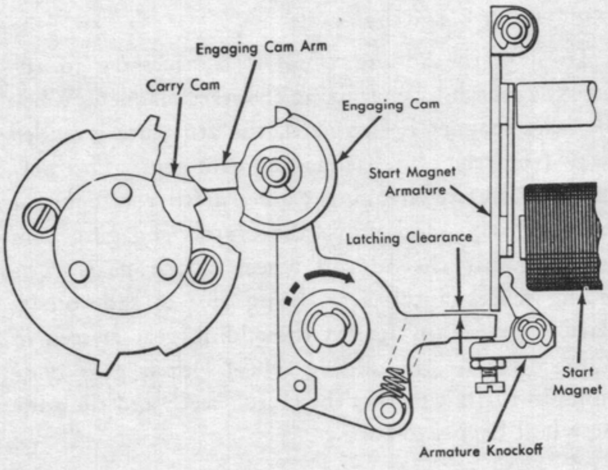
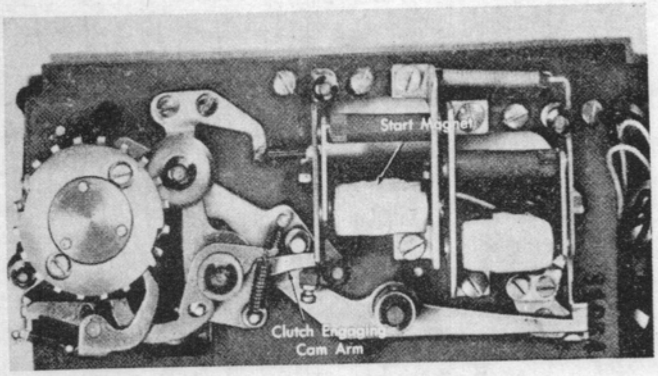


Figure 142. Carry Cam Dis-Engaging Clutch



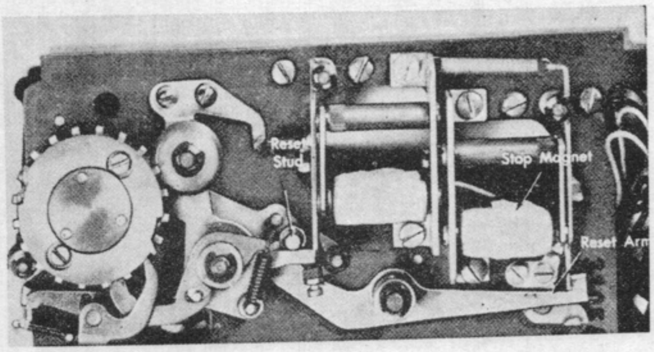


Figure 143. Stop Magnet Dis-Engaging Clutch

engaged at 183°, the first lobe of the carry cam disengages it at that time as shown in Figure 142. The second lobe disengages it at 255° if it is engaged after 183° and before 255°. The reasons for this will be explained in detail later. The second means of disengaging the clutch is by electrically energizing the stop magnet. When the stop magnet is energized, the reset arm is free to rotate in a counterclockwise direction. As it rotates, the reset stud strikes the clutch engaging cam arm, driving it in a clockwise direction. The clutch engaging cam arm is rotated far enough for the armature of the start magnet to move out over the clutch engaging cam arm and relatch it. As the clutch engaging arm rotated clockwise, it should be noted that the clutch engaging cam was pulled away from the adding wheel clutch gear, permitting the clutch to disengage by spring action. Figure 143 shows a counter, first with the clutch engaged and then disengaged as a result of energizing the stop magnet. The reset arm will be relatched on the armature by a stud on the back of the driven gear.

Add Wheel Detent

An adding wheel detent is provided to assure a positive positioning of the add wheel when the clutch is not engaged. The detent is mounted over a collar of the clutch engaging cam arm and held by a spring so that it moves with the clutch engaging cam arm. As the clutch engaging cam arm rotates counterclockwise to engage the clutch, the detent is pulled free of the detent wheel. This action frees the add wheel so that it can be rotated when the clutch teeth are meshed. When the clutch is disengaged, the detent again moves into the detent wheel to insure its being correctly positioned and held. This action can be seen by observing Figures 142 and 143.

9-10 Contact and Cam

A 9-10 contact and cam is provided to enable the counter to recognize when the amount accumulated in a counter has reached nine or more. The 9 and 10 contact cam is the outermost part of the adding wheel assembly and has three different levels. In Figure 144 the 9-10 contact arm rides the surface of the 9-10 contact cam. The majority of the cam surface consists of the intermediate level. The 9-10 contact arm controls the position of the 9-10 brush. During the time that the contact arm is riding on the intermediate level of the cam, the 9-10 brush is not making on either side of the contact assembly.

In Figure 144, the 9-10 contact arm is resting on the zero position. As the adding wheel assembly rotates counterclockwise, the position directly beneath the contact arm progresses until the contact arm drops into the low dwell. The low dwell of the cam represents the nine position and when the contact arm is in the low dwell the 9-10 brush is permitted to move, under spring tension, until it is making

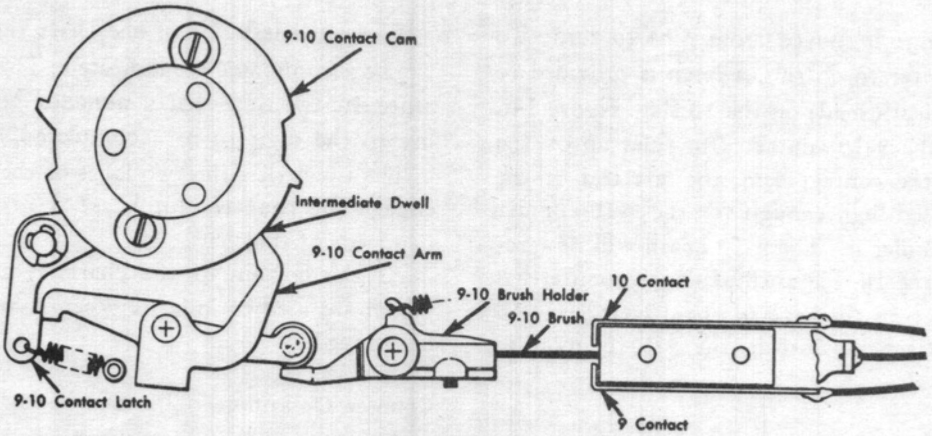


Figure 144. 9-10 Contact Cam, Arm, and Contact

contact on the 9 side of the 9-10 contact assembly as seen in Figure 145. The contact now indicates that a nine is in the counter.

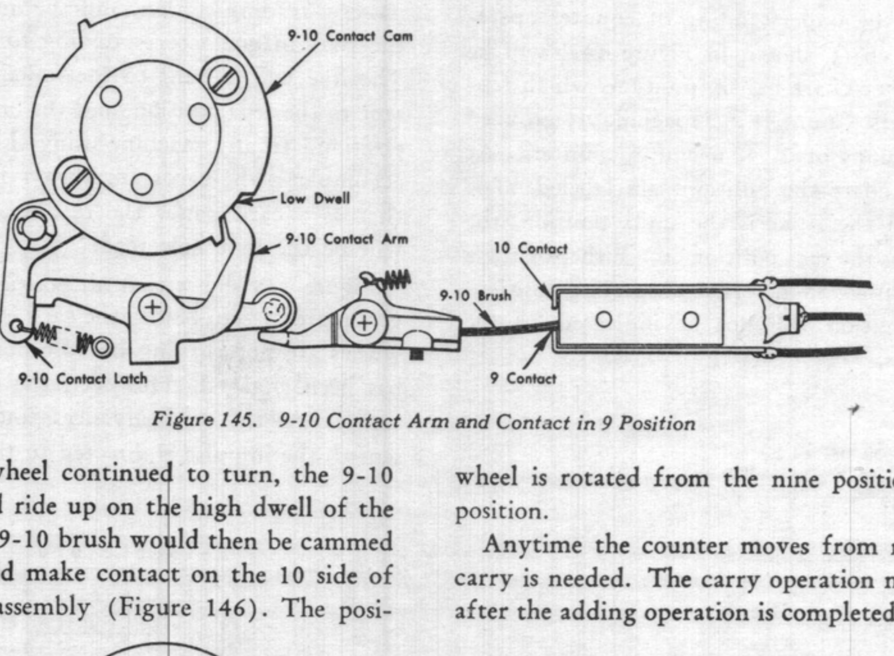


Figure 145. 9-10 Contact Arm and Contact in 9 Position

If the adding wheel continued to turn, the 9-10 contact arm would ride up on the high dwell of the contact cam. The 9-10 brush would then be cammed up so that it would make contact on the 10 side of the 9-10 contact assembly (Figure 146). The position immediately following the nine position is the zero position. It can be concluded then that the 9-10 contact will make on the 10 side whenever the adding wheel is rotated from the nine position to the zero position.

Anytime the counter moves from nine to zero, a carry is needed. The carry operation must take place after the adding operation is completed so the counter

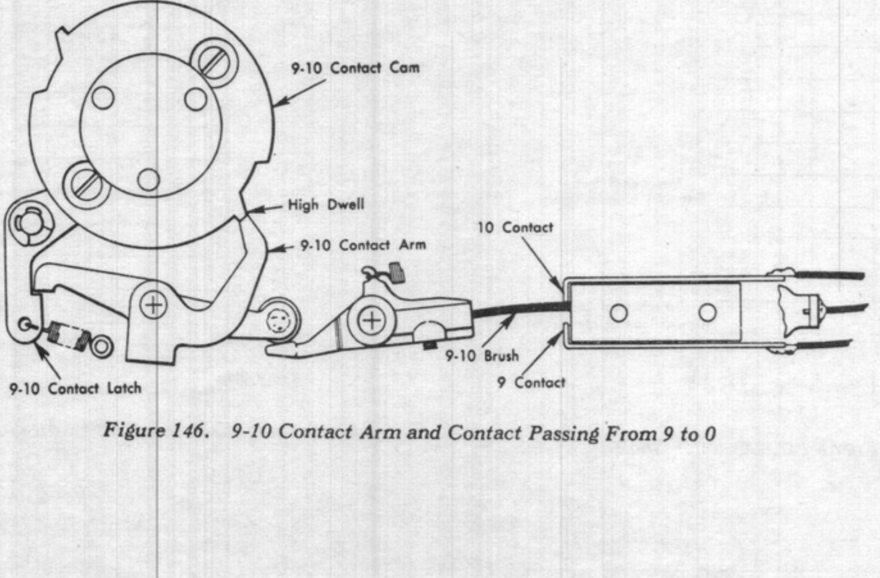


Figure 146. 9-10 Contact Arm and Contact Passing From 9 to 0

must remember if it moved from nine to zero. To enable the counter to do this, a latch is provided to hold the 9-10 brush made on the 10 side. Figure 146 shows that as the 9-10 contact arm rides up on the high dwell of the contact cam, the left end of the arm will be raised high enough for the 9-10 contact latch to move under it. The 9-10 brush will now remain made on the 10 side until after the counter has carried. A roller on the back of the driven gear will then trip the latch permitting the 9-10 contact to return to normal.

Counter Emitter

The counter emitter, on the 402 type counter, is used for summary punching and conversion operation which will be covered when the machine is studied.

Counter Chart

To facilitate the understanding of counter operation, a counter chart, shown in Figure 147, will be used. The counter chart has six positions which represent six counters. Counters in a machine are grouped into counter groups of 2, 4, 6 and 8 counters. At the top of the chart the positions are labeled. The first position on the right is the units position, the second position is the tens position etc. Either of these terms may be used to describe a specific position. The counter position will not be indicated on the following charts.

Along the left side of the chart the numbers that can be accumulated are indicated. These numbers also represent the time that a punched hole, corresponding to the digit to be accumulated, would be read.

The times that the two lobes of the carry cam disengage the counter clutch are shown on the right-hand side of the chart.

At the bottom of the chart, symbols are shown which are used to indicate when a counter is started or stopped.

Counter Operation

To illustrate counter operation, a problem will be studied using a counter chart. The number 195 is to be accumulated in a six-position counter group. The counters are all in the zero position.

The number 195 is to be read from a card as it passes a reading station, and the impulses directed to the start magnet corresponding to the position read. The five will be sent to the units position, the nine sent to the tens position, and the one to the hundreds position. In any machine using this type counter to accumulate, the cards are always fed 9-edge first so that as a card passes the reading brushes, the nine will be the first hole read.

Figure 148 shows that all positions of the counter group are at zero before the card is read. The adding wheels are not turning because none of the clutches has been engaged. However, the driven gear is rotating. As the card advances, and the nine hole is sensed, the impulse is directed to the start magnet in

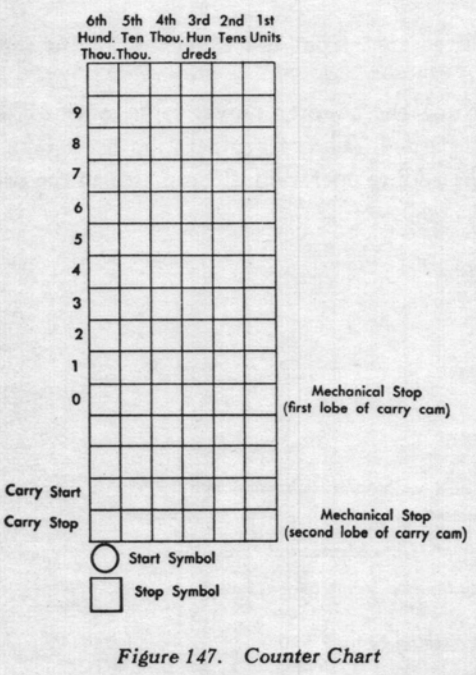


Figure 147. Counter Chart

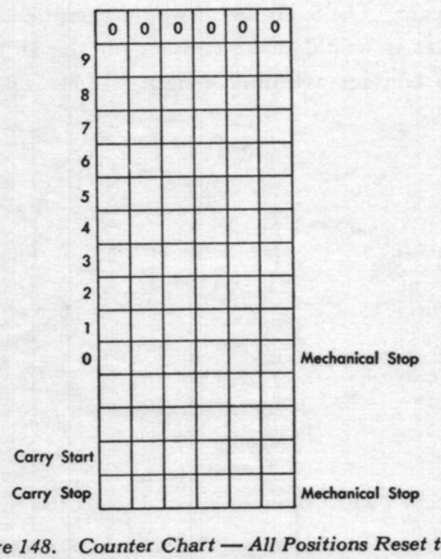


Figure 148. Counter Chart — All Positions Reset to Zero

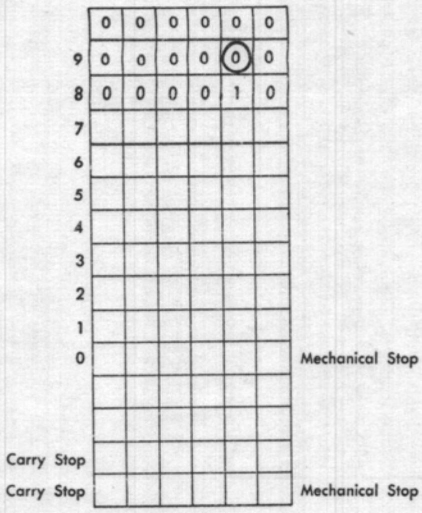


Figure 149. Counter Chart

the tens position. This is shown on the chart by a start symbol in the tens position opposite the nine (Figure 149). One cycle point later when an eight would be read, the add wheel in the tens position has advanced to the one position. None of the other counters has turned because their start magnets have not been energized. The next hole to be read is the five hole in the units position of the card. The impulse resulting from sensing the five hole energizes the start magnet in the units position (Figure 150). The add wheel of the tens position counter has advanced to the four position, and none of the others has advanced.

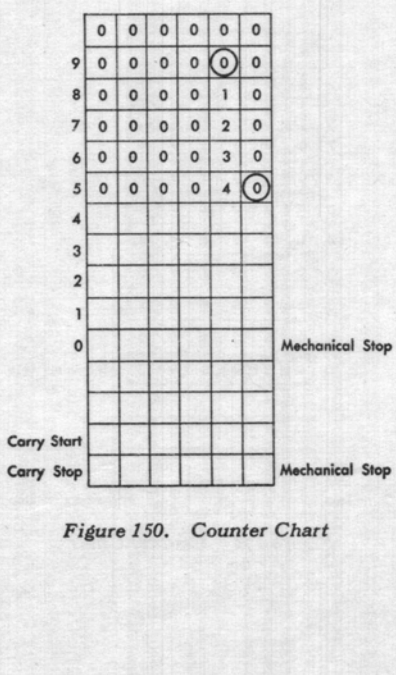


Figure 150. Counter Chart

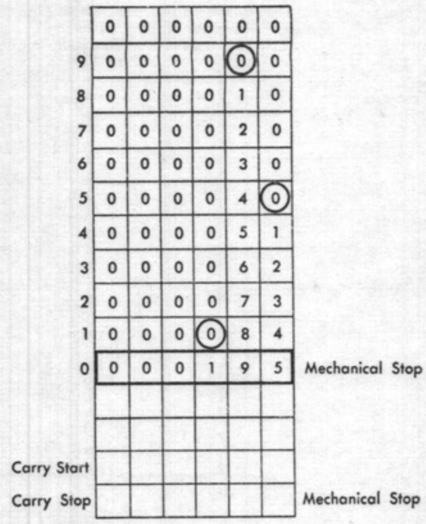


Figure 151. Counter Chart

Figure 151 shows the counter chart at zero time when all positions which have been started are stopped by the first lobe of the carry cam. The counter now contains the number 195. The counter group did not accumulate enough in any position to cause a carry so the amount shown at zero is the total amount accumulated.

The circuits required to add are shown in Figure 152. The counter chart shows that the only electrical impulses necessary were the impulses to the start magnets. The impulses result from reading a hole in the card and are available at a hub on the control panel. The wiring to the start magnet also terminates at a hub on the control panel. They are arranged this way so that any brush position may be wired to any counter position for flexibility.

The counter numbering in Figure 152 may appear to be inconsistent. However, it is consistent with the punching in the card columns to facilitate wiring. For example, if the amount to be accumulated is punched in columns 61 through 66, the units position of the amount would be punched in column 66. Column 66 would be wired to counter six, etc., which would eliminate confusion in wiring and result in a neater control panel.

Assume that a second card is now passing the brushes and that columns 61 through 66 are punched 000908. This amount is wired to be accumulated in

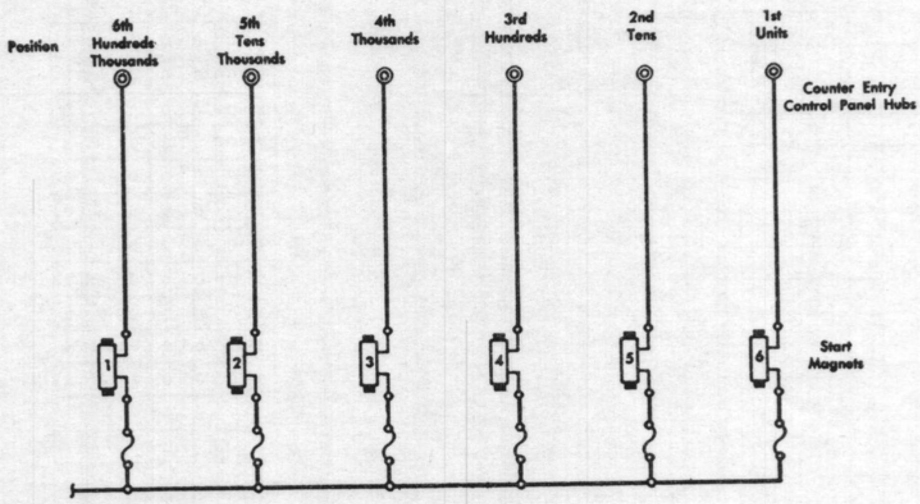


Figure 152. Circuit Necessary for Adding Only

the counter group which already contains the amount 195 from the preceding card. The chart shown in Figure 153 shows, at the top, that the amount 195 is already in the counter.

From this same figure it can be seen that the third position is started when the nine is sensed in column 64. The units position start magnet is impulsed when the eight is sensed in column 66. The important thing to note at this time is that, as the units counter advances from four time to three time, the counter add wheel advances from nine to zero. As this occurs, the 9-10 brush makes contact on the tens side and is latched in this condition. This enables the machine to remember to carry. A notation should be made on the chart to indicate this. A "t" can be placed in the square just above carry time in the column in which it occurred to represent the 9-10 contact latched on the 10 side. This will assist in the correct completion of the chart. This notation should be made as soon as the adding wheel has advanced this far.

Figure 154 shows the operation complete with the exception of the carry operation. The actual amount in the counter before carry time is 000093 with the 9-10 brushes in the 1st and 3rd positions latched on the 10 side to initiate a carry into the next higher order positions. This figure also shows a start impulse in the 2nd, 4th, 5th and 6th positions at zero time. This happens because the zero holes are sensed at this time. The start magnets actually accept these impulses and the armatures release the engaging cam

	0	0	0	1	9	5	
9	0	0	0	1	9	5	
8	0	0	0	2	9	5	
7	0	0	0	3	9	6	
6	0	0	0	4	9	7	
5	0	0	0	5	9	8	
4	0	0	0	6	9	9	
3	0	0	0	7	9	0	
2							
1							
0							Mechanical Stop
Carry Start							
Carry Stop							Mechanical Stop

Figure 153. Counter Chart

	0	0	0	1	9	5	
9	0	0	0	1	9	5	
8	0	0	0	2	9	5	
7	0	0	0	3	9	6	
6	0	0	0	4	9	7	
5	0	0	0	5	9	8	
4	0	0	0	6	9	9	
3	0	0	0	7	9	0	
2	0	0	0	8	9	1	
1	0	0	0	9	9	2	
0	0	0	0	0	9	3	Mechanical Stop
				t		t	
Carry Start							
Carry Stop							Mechanical Stop

Figure 154. Counter Chart

arms. However, before the clutches can be engaged, the first lobes of the carry cams lift the engaging cam arms back to a latched position on the start magnet armatures. It is not necessary to show these impulses at zero time.

Carry Operation

Another fundamental fact must be considered before this problem can be completed. If, manually, the number five is added to 95, it is immediately recognized that a carry into the tens position is necessary. In addition, because the carry is directed to a position which has a value of nine, it is also necessary to carry into the hundreds position. In a manual operation, the carry is made in one position and later in another position. However, in machine operation, all carrying must take place at the same time. It is, therefore, necessary that the machine recognize when a carry is made into a position which contains a nine, and not only accept the impulse, but immediately pass it on to the next higher order position.

Figure 155 shows the previous problem completed and illustrates the principles of carrying. The carry into the second position was the result of the 9-10 brush in the first position being latched on the 10 side. The carry into the 4th position was the result of the 9-10 brush being latched on the 10 side in the 3rd position. However, the impulse to carry in

	0	0	0	1	9	5	
9	0	0	0	1	9	5	
8	0	0	0	2	9	5	
7	0	0	0	3	9	6	
6	0	0	0	4	9	7	
5	0	0	0	5	9	8	
4	0	0	0	6	9	9	
3	0	0	0	7	9	0	
2	0	0	0	8	9	1	
1	0	0	0	9	9	2	
0	0	0	0	0	9	3	Mechanical Stop
	0	0	0	0	9	3	
	0	0	0	0	9	3	
Carry Start	0	0	0	0	9	3	
Carry Stop	0	0	1	1	0	3	Mechanical Stop

Figure 155. Counter Chart

the 3rd position was the result of the 9 in the 2nd position passing on the impulse it received from the 1st position. All counters that are started for carrying are stopped by the second lobe of the carry cam. The sum is now correct and may be checked manually.

To facilitate the understanding of the carry operation, the circuits necessary for carrying will be added to those which were necessary to merely add the amount from one card. The necessary wiring is shown in Figure 156 and the 9-10 brushes are in po-

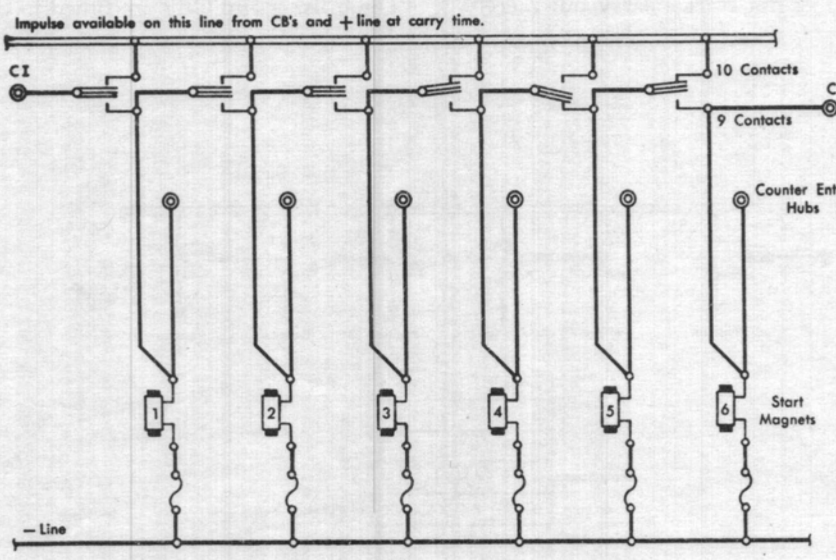


Figure 156. Circuit Necessary for Adding with Carry

sition to provide the necessary carry for the problem just completed. It will be remembered that the 9-10 brushes in the first and third positions were latched on the 10 side. The 9-10 brush of the second position was made on the nine side, because this counter contained a nine and the low dwell of the 9-10 contact cam represents the nine position.

At carry time, an impulse from the plus side of the line through a cam operated contact is available at the 10 side of all 9-10 contact assemblies. Any or all 9-10 brushes made on the ten side receive this impulse at precisely the same instant. In this case the first and third brushes accept this impulse. In the third position, the impulse travels through the brush to the 9 side of the 9-10 contact assembly in the next higher order position (Position 4). It then goes straight down to impulse the start magnet of position four (Counter #3), to the fuse and the negative side of the line.

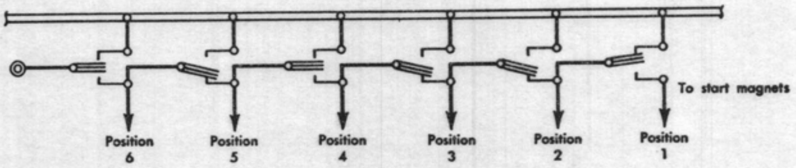
In the first position, the impulse passes through the brush and follows a similar path to impulse the start magnet in the second position. However, at the same time, a parallel circuit is available from the 9-10 brush in the first position through the 9 side of the 9-10 contact assembly in the second position to the start magnet of the third position counter. This happens because the counter recognizes a nine in the second position by the 9-10 brush making contact on the nine side.

The nine side is only effective when a carry is made into a position which contains a nine. A brush making on the nine side does not start a carry but merely passes the impulse along, if it receives one. However, it should be noted that, if several nines are in adjacent counters and the first receives an impulse to carry, the impulse is passed on until a nine is not encountered. Figure 157 illustrates this. In this figure, the 9-10 contact is latched on the 10 side in the first position only. This will initiate a carry into the second position, but, since there is a nine in the second position, the third position will also carry. There is also a nine in the third position which causes the fourth position to carry. However, the impulse will not be passed on to the fifth position because the 9-10 brush of the fourth position is not making on the nine side. Also note that even though the 9-10 brush in the fifth position is making on the nine side there is no carry into the sixth position as a result.

Timing

The adding wheel must advance one position for every unit to be added. This requires that the adding wheel advance one position for every cycle point the clutch is engaged. To better understand the actual operation of the counter, a few timings relative to the index should be considered.

This type of counter is used only in machines having 20 cycle points per cycle. This results in each cycle point containing 18 degrees. The adding wheel must turn during 18 degrees on the index for each unit to be added. If a nine is to be accumulated in a counter, the counter must turn for $18° \times 9 = 162°$. The brushes and CB's are timed so that a nine is sensed



	0	9	6	9	9	3	
	0	9	6	9	9	3	
	0	9	6	9	9	3	
Carry Start	0	9	6	9	9	3	
Carry Stop	0	9	7	0	0	3	Mechanical Stop

Figure 157. Carry into Positions Containing 9's

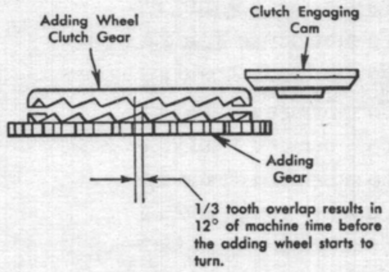


Figure 158. Counter Clutch Tooth Overlap

at 9°. The start magnet is energized at 9°, but the adding wheel does not begin to turn immediately. Figure 158 shows that when the start magnet is impulsed, and the clutch attempts to engage, the teeth are not in a position to mesh fully. This is done to allow time for the teeth on the adding wheel clutch gear to engage the next tooth on the adding gear. The teeth on the driven gear overlap the teeth on the adding wheel assembly by a third of a tooth or 6°. From this, it is easily seen that the driven gear must turn 12° before the clutch teeth mesh. Now recall that the impulse reading a 9 hole is available at 9°, that there is a 12° lag before the adding wheel starts to turn, and that the adding wheel must turn 162° to accumulate a nine. The time on the index when the adding wheel must stop is the sum of these or 9° + 12° + 162° = 183°. The first lobe of the carry cam must disengage the adding wheel clutch at that time.

Assume that an eight is to be accumulated. An 8 hole is sensed 18° later than the 9 hole so it is sensed at 27°. The adding wheel must turn 18° x 8 = 144°. Therefore, the adding wheel must be stopped at 27° + 12° + 144° =183°. The time when the adding wheel should stop can be checked in this manner for each digit, and it will be found to be 183° in each case. However, if a zero hole is sensed, the adding wheel should not advance. A zero hole is sensed at 171° and the clutch would engage 12° later at 183°, but at 183° the clutch is disengaged by the first lobe of the carry cam. This prevents the adding wheel from advancing when the start magnet is energized from a zero hole. Complete the table in Figure 159.

The start magnet is energized at 225° for the carry operation. It is only necessary to advance the adding wheel 18° or one position to carry. Therefore, the second lobe on the carry cam must disengage the clutch at 225° + 12° +18° = 255°.

PRINCIPLES OF SUBTRACTION

THE FOLLOWING is an example of manually subtracting one number from another.

$$\begin{array}{r} 46983 \\ -21692 \\ \hline 25291 \end{array}$$

Theoretically there are two possible ways of performing this operation in a counter. One is to turn the counter wheel backwards. The second is to add a figure which will advance the counter to the correct position.

The driving gear turns in only one direction, however, and the adding wheel clutch teeth are cut so that the counter wheel will only turn in one direction. The alternative is to accomplish subtraction by adding the complement of the number to be subtracted.

Figure to be added	Hole in card	CB Time (Degrees)	Start Magnet Energized (Degrees)	Add Wheel Starts (Degrees)	Add Wheel Stops (Degrees)	Add Wheel has turned (Degrees)	Add Wheel has turned (cycle point)
9	9	9	9	21	183	162	9
8							
7							
6							
5	5	81	81	93	183	90	5
4							
3							
2							
1							
0							

Figure 159. Counter Table

Subtraction — Type 405 Machine

When this counter is used in a type 405 machine, the complement of any number can be determined by subtracting that number from a figure made up of 1 followed by as many zeros as there are positions in the counter group to be used. For example, to determine the complement of 1,234 when using a 6-position counter, subtract 1,234 from 1,000,000 as follows:

```
1,000,000
    1,234
---------
  998,766
```

In other words, the complement is obtained by subtracting the first significant figure at the right from 10, and all other positions to the left from 9. The first significant digit is a complement on a ten base, while all digits to the left are complements on a nine base.

```
9999910
00123 4
-------
99876 6
```

With a figure ending in zeros (012300), the same rule applies: subtract the first significant digit at the right from 10 and all other digits from 9.

```
9991000
012 3 00
--------
987 7 00
```

Therefore, for the first significant digit of an amount to be subtracted, subtraction is accomplished by adding the difference between 10 and the digit to be subtracted. Thus:

To subtract 9, add a 1
To subtract 8, add a 2
To subtract 7, add a 3
To subtract 6, add a 4
To subtract 5, add a 5
To subtract 4, add a 6
To subtract 3, add a 7
To subtract 2, add an 8
To subtract 1, add a 9

For all positions to the left of the first significant digit, subtraction is accomplished by adding the difference between nine and the digit to be subtracted. Thus:

To subtract a 9, add a 0
To subtract an 8, add a 1
To subtract a 7, add a 2
To subtract a 6, add a 3
To subtract a 5, add a 4
To subtract a 4, add a 5
To subtract a 3, add a 6
To subtract a 2, add a 7
To subtract a 1, add an 8
To subtract a 0, add a 9

Counter Operation — Subtraction

First, it is necessary to know when and how the counter adding wheel must start and stop. Figure 160 shows how a complement is added. The number to be subtracted is 7, and if it is the first significant digit, its complement is 3. A 3, then, is the number to be added.

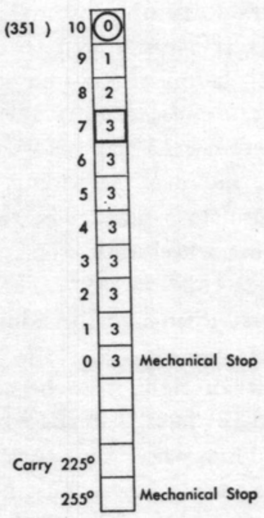


Figure 160. Subtraction in the Units Position

It should be remembered that the machine will sense a 7 hole and the impulse must result in a 3 being added. The 7 impulse would normally cause the add wheel to start and the counter to accumulate a 7. However, if the counter is started 3 cycle points earlier and stopped by means of the 7 hole being sensed, a 3 will be accumulated. The impulse, to start the counter, would have to be available one cycle point before 9 time which will be referred to as 10-time hereafter.

The index time for this impulse would be 351°, 18° before 9 time (9°). It should be recognized that, if the start magnet in the units position is impulsed at 351°, and the stop magnet is impulsed from the hole in the card, the correct complement will be added for any digit punched in the card.

In all positions to the left of the first significant digit, the number added should be based on a 9's complement. Therefore, to add the correct complement of a digit in one of these positions it would be necessary to energize the start magnet at 9-time and stop it by an impulse from a hole in the card. Note that if a 9 is to be subtracted, a zero should be added or in other words, the adding wheel should not advance. In this case the start magnet and the stop magnet receive an impulse at the same time. When this occurs, the clutch engaging cam arm will be relatched before the adding wheel can advance.

The following problem illustrates these principles. Assume two cards are fed through the machine and the amounts are accumulated in a six-position counter group. The first card is punched 006902 and is added. The second card is punched 001945 and is subtracted. This problem is done manually and the result is shown below.

$$\begin{array}{r} +006902 \\ -001945 \\ \hline +004957 \end{array}$$

The counter operation for this problem is shown in Figure 161. The information accumulated on the first cycle is added, in the manner previously described, with the impulses from the brushes starting the counters and the counters being stopped by the first lobe of the carry cams.

+ 6902

10	0	0	0	0	0	0	351°
9	0	0	0	0	0	0	9°
8	0	0	0	1	0	0	27°
7	0	0	0	2	0	0	45°
6	0	0	0	3	0	0	63°
5	0	0	1	4	0	0	81°
4	0	0	2	5	0	0	99°
3	0	0	3	6	0	0	117°
2	0	0	4	7	0	0	135°
1	0	0	5	8	0	1	153°
0	0	0	6	9	0	2	Mechanical Stop 183°
	0	0	6	9	0	2	
	0	0	6	9	0	2	
225°	0	0	6	9	0	2	225°
255°	0	0	6	9	0	2	255°

− 1945

10	0	0	6	9	0	2
9	0	0	6	9	0	3
8	1	1	7	9	1	4
7	2	2	8	9	2	5
6	3	3	9	9	3	6
5	4	4	0	9	4	7
4	5	5	1	9	5	7
3	6	6	2	9	5	7
2	7	7	3	9	5	7
1	8	8	4	9	5	7
0	9	9	4	9	5	7
	9	9	4	9	5	7
	9	9	4	9	5	7
225°	9	9	4	9	5	7
255°	0	0	4	9	5	7

Figure 161. Counter Chart — + 6902 − 1945

The numbers sensed from the second card are subtracted by adding the complement of 1945. The impulse used to start the units position counter occurs at 351° or 10-time, and is referred to as a "hot 10" impulse. The impulse which starts all other counters in the counter group comes at 9-time (9°) and is called a "hot 9" impulse. In the columns where a digit is sensed, the resulting impulse is directed to the stop magnet to stop the adding wheel. In positions where no hole or a zero hole is sensed, the counters are stopped at zero by the first lobe of the carry cams or the zero impulse.

The carry operation takes place in a normal manner with the 9-10 brush latched on the ten side initiating a carry. Positions which receive an impulse to carry and contain a 9, also pass this impulse on to carry in the next higher order position. The high order position counter attempts to pass the carry impulse on because it contains a nine, but there is no path for current flow.

The counter circuit as shown for adding operations is not adequate for subtracting. An impulse directed to the counter from a brush should energize the start magnet in an adding operation, but energize the stop magnet during subtraction. At times it is also desirable to neither add nor subtract the information in a card. These objectives are accomplished by controlling the counter with relay points. The relays whose points are used to control the counter

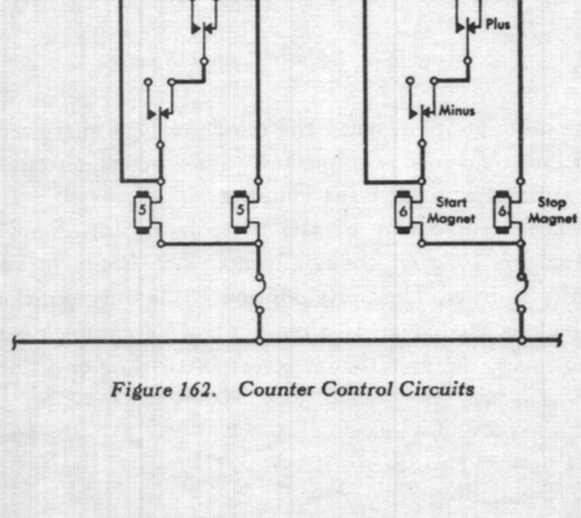


Figure 162. Counter Control Circuits

will be under the control of holes in the card which identify the information. Two relays are used, a plus relay and a minus relay. Figure 162 shows how the points of the relays are placed in the counter control circuits to instruct the counter to either add, subtract or not accept any information.

If neither the plus nor the minus relay is energized, the impulse received by the counter entry hub will not reach either the start magnet or the stop magnet. If the plus relay is energized, the impulse will be directed to the start magnet. If the minus relay is energized, the impulse will be directed to the stop magnet. A N/C minus relay point is placed in the circuit to the start magnet to open this circuit.

A means of starting the counter on a subtract operation is shown in Figure 163. The N/O minus relay point is used to provide a circuit from the start magnet in the units position counter, to a wire which is always hot at 10-time. In any position other than

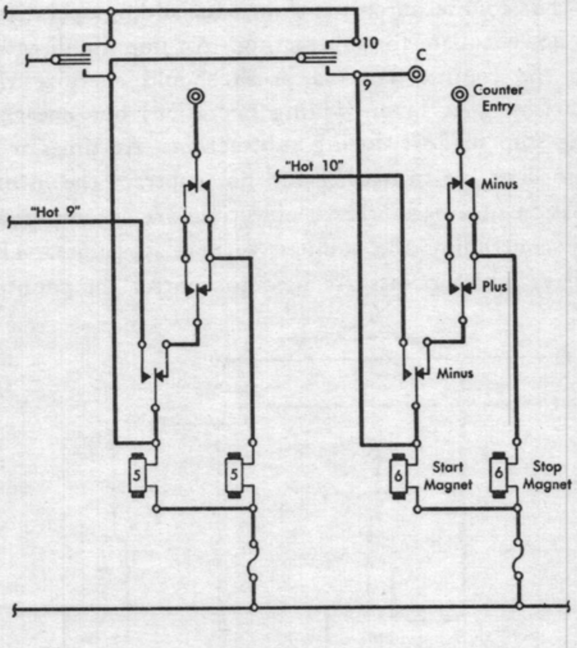


Figure 163. Counter Control Circuits

the units position, when the minus relay is energized, the start magnet is connected to a wire which emits a 9 impulse to start the counter.

The complement of the first significant digit is based on 10 even though it does not occur in the units position. The units position is the only position which is started at 10-time for a 10's complement. However, the fact that it starts at 10-time and does not contain a significant figure signifies that the adding wheel will turn until 183°, thereby adding ten. The 9-10 brush latches and initiates a carry into the tens position. If there is a significant digit in the tens position, the additional unit added, as a result of the carry, puts it on a tens base. However, if there is no significant digit in the tens position it will have added 9. The carry into that position causes it to advance to zero and carry into the third position, thereby putting the third position on a 10's base. There will be a 10 added in every position until the first significant digit is encountered. Figure 164 illustrates, by means of a counter chart, the way in which a counter locates the first significant digit. The number 005900 is subtracted from a counter which has not had anything accumulated in it previously, and the amount accumulated should now be the complement of the number added or 994100.

−005900

10	0	0	0	0	0	0
9	0	0	0	0	0	1
8	1	1	1	0	1	2
7	2	2	2	0	2	3
6	3	3	3	0	3	4
5	4	4	4	0	4	5
4	5	5	4	0	5	6
3	6	6	4	0	6	7
2	7	7	4	0	7	8
1	8	8	4	0	8	9
0	9	9	4	0	9	0
	9	9	4	0	9	0
	9	9	4	0	9	0
225°	9	9	4	0	9	0
255°	9	9	4	1	0	0

Figure 164. Counter Chart

Sign Indication

An accumulating mechanism should indicate the algebraic sign of the amount it contains. In Figure 164 the amount was negative and the counter contained a complement figure. In the preceding counter problem shown in Figure 161, the amount accumulated was positive, and the counter contained a true figure. In this way the algebraic sign is indicated. A complement figure (a negative sign) is indicated by a nine in the high order position. To be sure that the sign is always correctly indicated, it is necessary that the counter group always have a capacity of at least one position more than the maximum amount to be accumulated. If this is done, the high order position will always contain a zero if the amount is plus, i. e., a true figure. It will always contain a nine if the amount is a negative or complement figure. As an example of the rule, if amounts are to be accumulated and the total may contain as many as four digits, a four position counter group could not be used. A four position total would require a five-position counter group. However, because counters are grouped in 2, 4, 6 and 8 position counter groups, a six or eight position counter group would be necessary.

Subtraction — Type 402 Machine

Type 402 machine uses the same counter as the Type 405 and its functions are identical. However, a subtract operation differs slightly from the Type 405 subtract operation in that a complement system based on a 9 in all positions including the units position is used.

It can be seen from the following example that if a number is subtracted from another number and the balance remains positive, the units position will be one low. The number in the counter is 862. The number to be subtracted is 495. Therefore, 999504 would be added, assuming a six-position counter. The results would be as follows:

```
0 0 0 8 6 2
9 9 9 5 0 4
-----------
9 9 9t3 6 6
1 1 1
-----------
0 0 0 3 6 6
```

Figure 164A

The result should be 000367 so the counter is one low. As more cards are accumulated, the error will increase. This operation is not satisfactory, obviously, as the amount accumulated must be accurate.

Now recall that in an earlier example the high order position attempted to carry, but could not. This was because the nine side of the 9-10 contact was trying to pass the impulse on, but the 9-10 brush was not connected to a start magnet. However, the 9-10 brush in the high order position is connected to a control panel hub labeled CI (Figure 156). The hub CI (carry impulse) emits an impulse when the high order position attempts to carry. It should also be noted that the 9 side of the 9-10 contact in the units position counter is connected to a control panel hub, C. The C hub is a carry entry hub which accepts a carry impulse. If the CI hub is connected to the C hub by control panel wire (Figure 165) when the same two cards are run through the machine, the result is as follows:

```
0 0 0 8 6 2
9 9 9 5 0 4
-----------
9 9 9t3 6 6
1 1 1 0 0 1
-----------
0 0 0 3 6 7
```

Figure 164B

The result is now correct because the high order position carried back into the units position. When the counter contains a true figure, this will occur every time an amount is subtracted and the total remains positive. If the amount in the counter is negative, it will occur every time an amount is subtracted or when an amount is added that will make the sign positive.

The counter wiring is the same as for the 405 with one exception. The units position start magnet

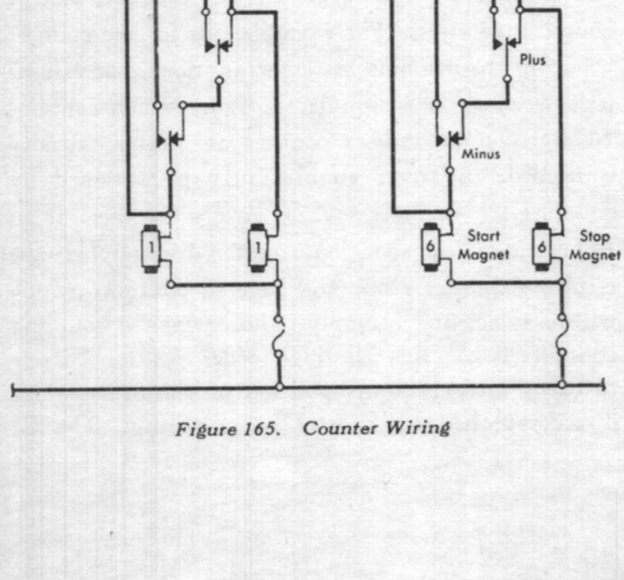


Figure 165. Counter Wiring

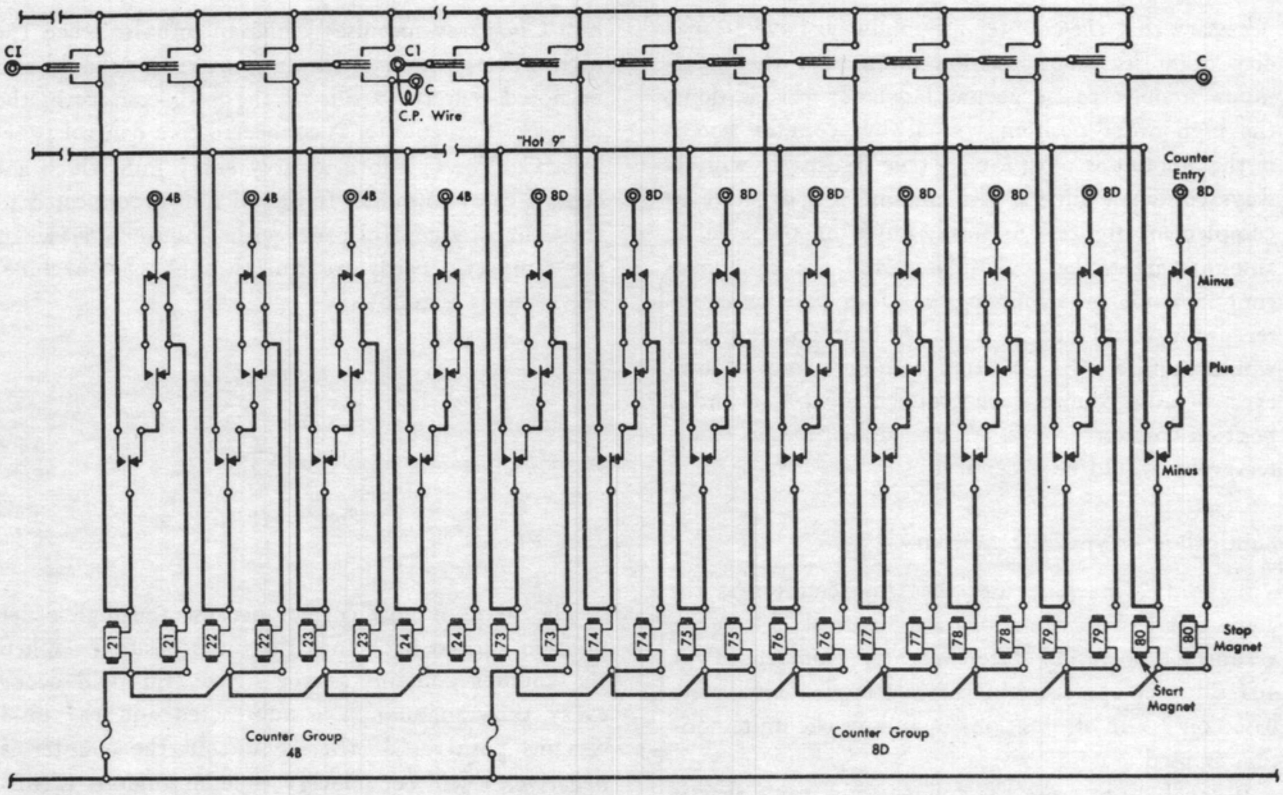


Figure 166. Counter Coupling

is connected to the "hot 9" wire when the minus relay is energized, as are the other positions. The CI and C control panel hubs must be connected by control panel wiring.

Counter Coupling

The CI and C hubs serve another purpose, that of coupling counters. For example, the largest counter group in the machine has eight positions, but assume it is necessary to accumulate a figure which contains 10 digits. Obviously a counter of greater capacity is needed. A larger counter may be obtained by coupling two or more counter groups together. If an eight and a four position counter are coupled, the resulting counter group will have 12 positions, which will be sufficient. The only requirement for coupling counters is to cause the high order position of one to carry into the units position of the other. This is accomplished by control panel wiring. The CI hub of the low order counter group is wired to the C hub of the high order counter group. Figure 166 shows two counters coupled together.

The counter groups have been labeled to facilitate description. With the control panel wiring as shown, counter 80 is the units position counter, and counter 21 is the high order position counter. However, the person wiring the control panel will determine which is the low and high order counter groups. If the control panel wire is inserted so that it will connect the CI hub of counter group 4B and the C hub of counter group 8D, then counter 24 is the units position and counter 73 the high order position counter.

Read Out and Reset

The read out and reset of the 402-405 type counter is done in one operation. As a counter reads out the information it contains, the counter adding wheel must stop at its zero position. The counter may have any number in it at the time the counter is to be cleared or reset. For this reason, the mechanical stop at 183° is not a satisfactory way to stop the adding wheel. The counters may be stopped by energizing the stop magnet when the counter adding wheel reaches zero. Recall that the 9-10 brush makes on the 10 side to recognize when the counter reaches zero. The timed impulses are available at the 10 side of the 9-10 contact so that when the 9-10 brush makes, an impulse is directed to the stop magnet and to a counter exit hub. The stop magnet will stop the counter adding wheel at zero and the counter exit hub can be wired to a print magnet or counter entry hub as desired by the operator.

The time that the impulse is available is as important as it has been in previous operations. The counter and type bars must be synchronized so that the information reading out of the counter will reach the type bar when the type bar is in a position to print the correct information. Information is also read from a card and printed, which signifies that the card movement and sensing, readout, and type bar movement must all be synchronized.

For this to be true, the adding wheel must reach zero at the time corresponding to the digit to be read out. For example, if the counter contains a nine to be read out, the adding wheel must reach zero at 9-time. The same is true of all other digits. If the counter has a nine, it must advance only one position to be at zero. The counter should be started one cycle point before 9-time or at 351° to cause it to reach zero at 9-time. A counter which contains an eight would have to advance two cycle points to reach zero. Therefore, it would have to be started at 351° or 10-time, to reach zero at 8-time. It will be found that for every digit, the counter will have to be started at 351° to reach zero at a time corresponding to the digit read out. This is illustrated by the counter chart in Figure 167.

The counter chart shows that all positions in a counter clearing on a total cycle move from 9 to zero and latch the 9-10 contact on the 10 side. It is not desirable to carry after the counters have been reset to zero, so a means must be provided to prevent it.

From a circuit standpoint the objectives to be accomplished are as follows:

1. At 10-time, start all counters in the counter group which is to read out and reset.
2. Provide a circuit to the stop magnet and counter exit hub from the 10 side of the 9-10 contact as the counter advances from nine to zero.
3. Prevent a carry during a total cycle.

10	0	5	9	0	2	3
9	1	6	0	1	3	4
8	2	7	0	2	4	5
7	3	8	0	3	5	6
6	4	9	0	4	6	7
5	5	0	0	5	7	8
4	6	0	0	6	8	9
3	7	0	0	7	9	0
2	8	0	0	8	0	0
1	9	0	0	9	0	0
0	0	0	0	0	0	0
	0	0	0	0	0	0
	c 0	c 0	c 0	c 0	c 0	c 0
225°	0	0	0	0	0	0
255°	0	0	0	0	0	0

Figure 167. Counter Chart — Readout and Reset

Figure 168 shows how these objectives are accomplished. A total relay point is added in the circuit to the start magnet. It will not affect the circuit during adding or subtracting because it will be normal, but on a total cycle, when the counter is to read out and reset, it will be transferred. The total relay N/O point now connects the start magnet to the "hot 10" impulse to start the counter at 10-time.

The 10 side of the 9-10 contact is connected to a wire which emits an impulse every cycle point for read out and resetting as well as one at 225° for carrying. When the 9-10 brush makes against the 10 side as the counter is advancing from nine to zero, an impulse is available through the brush to another total relay point which has been added. This point is transferred, and the impulse is sent through the normally open point to the counter exit hub, which is wired by a control panel wire to a print magnet, counter entry, etc. There is also a parallel circuit through the N/O total relay point, to the right and down to a N/C minus relay point as a terminal, up to and through the N/C plus relay point and down to the stop magnet. This circuit stops the counter, which has now been reset to zero.

The total relay point is transferred on a total cycle only, so that it will not interfere with normal carry operation. However, it will remain energized during the total cycle long enough to prevent a carry during the total cycle.

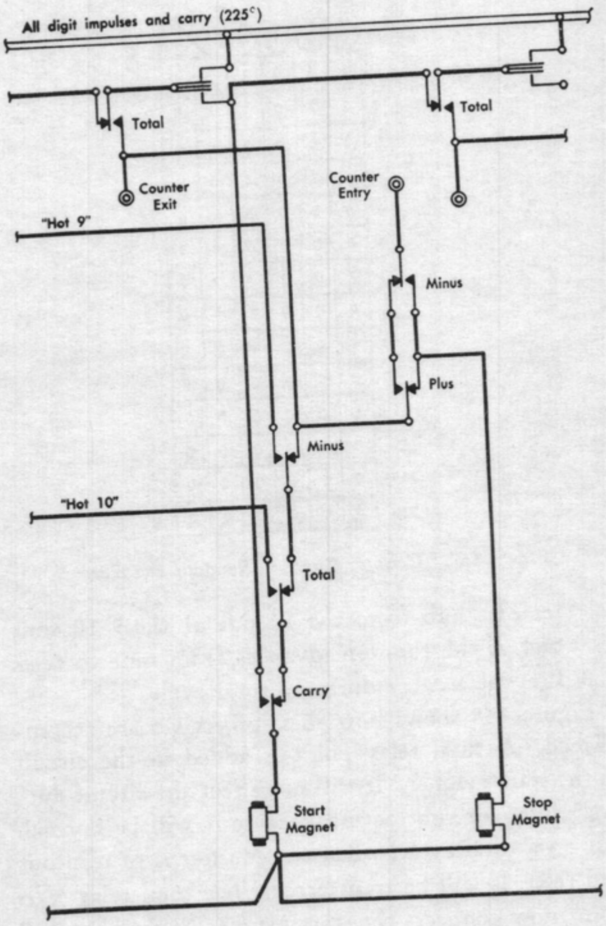


Figure 168. Control Circuits — Readout and Reset

Because the 10 side of the 9-10 contact is connected to CB's which emit all digit impulses and the carry impulse, another minor problem is presented. When the 9-10 brush makes on the 10 side of the 9-10 contact during an adding or subtracting operation, it will cause the next higher order position start magnet to be energized immediately, unless something is done to prevent it. To overcome this, a carry relay is used and its points are placed in the circuit so that a carry impulse will not reach the start magnet unless the relay is energized. The relay is controlled by a cam operated contact so that it will only be energized during carry time. It will not interfere with any other operation.

COUNTER OPERATION SUMMARY

Adding

The counter is started by an impulse to the start magnet resulting from a brush sensing a hole in a card.

The counter is stopped mechanically by the first lobe of the carry cam.

Carrying

The counter is started by an impulse to the start magnet originating from a 9-10 brush latched on the 10 side of the 9-10 contact at 225°.

The counter is stopped mechanically by the second lobe of the carry cam.

Subtracting

The counter is started automatically by an internal circuit completed to the start magnet.

The counter is stopped by an impulse to the stop magnet resulting from a brush sensing a hole in a card.

Read Out and Reset

The counter is automatically started at 351° by an internal circuit completed to the start magnet.

The counter is stopped, and the information read out, when the counter advances to zero, by an impulse to the stop magnet and counter exit hub. The impulse originates from 9-10 contact when the 9-10 brush makes contact on the 10 side.

RATCHET TYPE COUNTER

THE RATCHET type counter is another accumulating mechanism and is used in the Type 602A Calculating Punch. This counter is similar to the Type 402 counter in that it is driven by means of a continuously running drive shaft and drive gear. The counter accumulates about the same as the Type 402 counter. However, this counter may be referred to as a complement counter because it accumulates a complement figure for amounts to be added and accumulates true figures for amounts to be subtracted. This is exactly the reverse of the Type 402 counter operation, but the methods are the same, i. e., when accumulating complements both are started at 9-time and stopped by a hole in the card, etc. Consistent with the reversal of operation, this counter resets to 9 instead of zero. The start and stop magnets control a ratchet type clutch, from which it derives its name.

The ratchet type counter has no carry cam and the counter wheel and ratchet gear make one revolution for each adding operation. This eliminates the necessity for timing the counter to the machine cycle during installation.

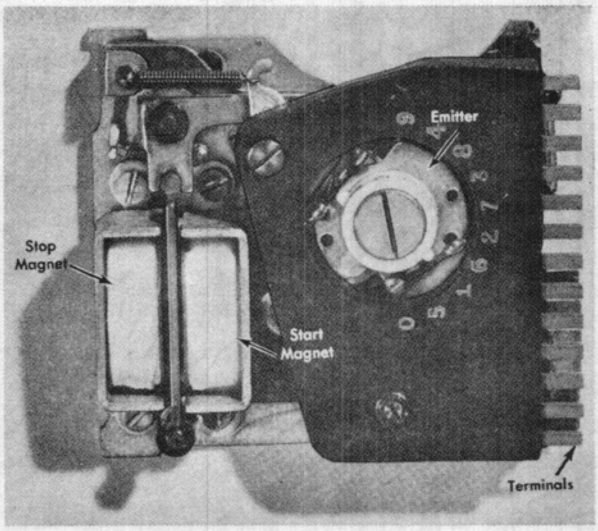


Figure 169. Ratchet Type Counter

The read out of this counter takes place through the emitter and does not require resetting to read out as the Type 402 counter does. However, it is capable of reading out and resetting in one operation which is controlled by the control panel wiring.

The ratchet type counter is pluggable, permitting removal and installation without disconnecting or connecting wires. Figure 169 shows the ratchet type counter, and from the illustration it can be seen that there is only one position per counter plate.

Mechanical Principles — Type 407 Counter

The ratchet type counter (Figure 170) used in the Type 407 is pluggable, permitting removal from the machine without disconnecting wires. This arrangement also makes it possible to wire the terminal mouldings before inserting counters. Both the ratchet

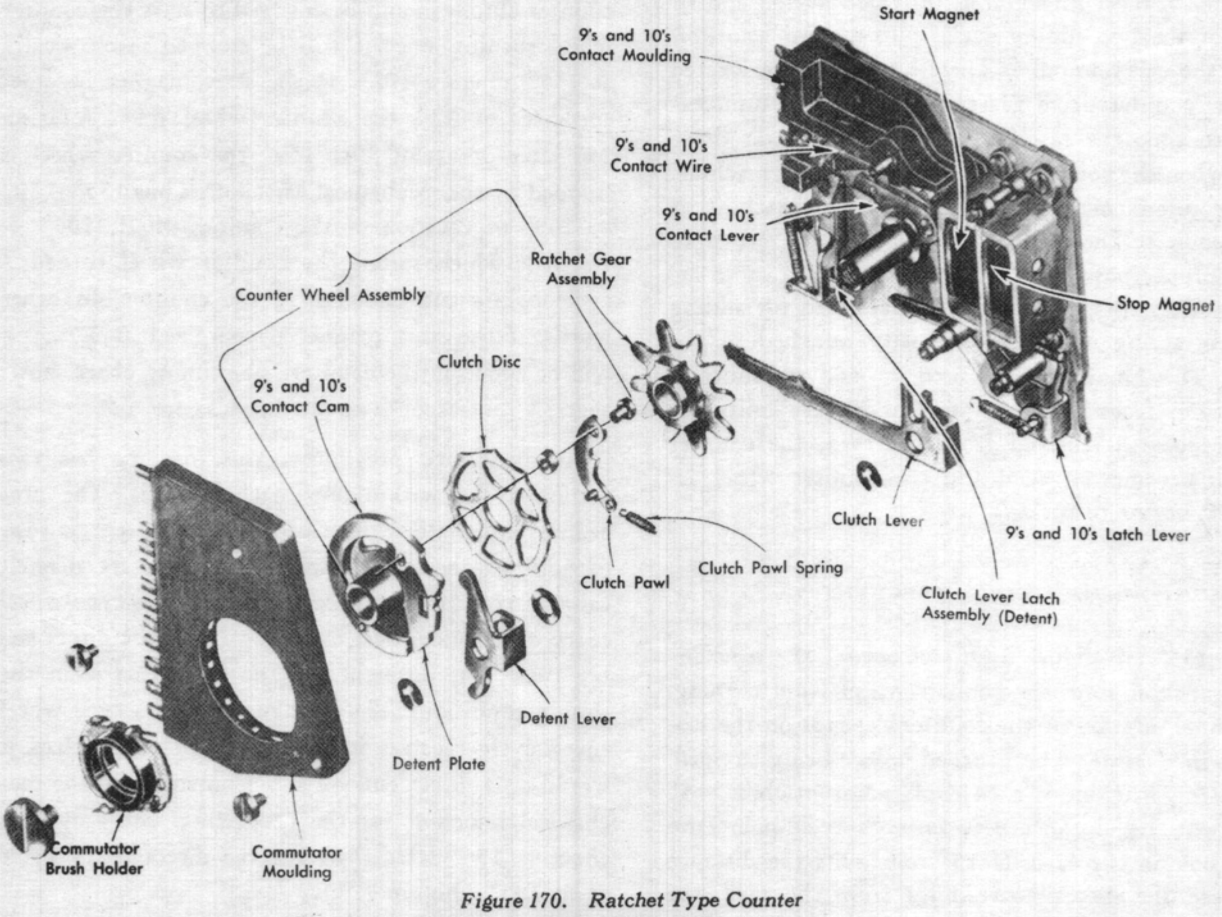


Figure 170. Ratchet Type Counter

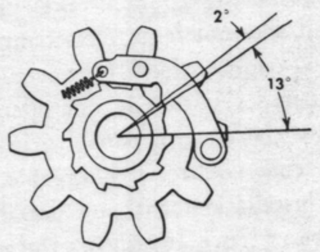


Figure 171. Counter Clutch Overlap

gear and ratchet have 10 teeth and allow one complete revolution of the counter wheel and ratchet gear for each adding operation. Since there are two adding cycles (direct entry and typewheel entry) of the counter for each machine cycle, there must be at least two complete revolutions of the ratchet gear for each machine cycle. The 407 is a 24 cycle point machine; consequently the counter drive gear has 24 teeth. Since the ratchet gear has 10 teeth and the counter drive gear has 24 teeth, the ratchet gear must make 2-2/5 revolutions for each machine cycle.

A mechanical knockoff is provided at the end of each of the two adding cycles plus a third knockoff after the carry impulse. These knockoffs are located on the counter drive gears, therefore, it is unnecessary to time the ratchet gear to the counter drive gear when the counters are inserted into the machine. The counters may be inserted into the machine at any point in the cycle; when reset, they return to their proper position.

Counters are accumulating devices used for adding or subtracting quantities normally punched in the card. They may also be used to add or subtract quantities from other counters or storage units. As the impulse is received from the card, the counter clutch becomes engaged and the counter wheel assembly begins to rotate.

COUNTER ADDING (DIRECT ENTRY)

At 155° (if adding by direct entry) the mechanical knockoff stops the counter wheel from turning. The final position of the counter depends on the distance the counter wheel turned before being stopped. Since this machine is a 24 cycle point machine, 15° represents the distance between each cycle point and each hole in the card. If 15° represents the distance between the successive readings from the card, the counter wheel must rotate 15° for each unit value to be accumulated. Thus, to add a 1, the counter wheel must turn for 15°; to add a 9, the counter wheel must turn 9x15 or 135°. At the time the start magnet receives the impulse to engage the counter clutch, the clutch pawl overlaps the ratchet assembly by 2° (Figure 171). Since there are 15° between the teeth on the ratchet, the ratchet must move 13° after the start magnet receives its impulse before the counter wheel actually starts to move. To add a 9 the impulse to the start magnet comes at 7° as noted by the timing chart. The counter wheel does not turn until 13° later or 20° on the index. As noted, in order to add 9 into the counter, the counter wheel must turn for 135°. Thus, to add a 9, the counter wheel starts turning at 20° and stops at 155°. The mechanical knockoff stops the counter wheel from turning at 155°. The mechanical knockoff starts to operate at 140° but does not actually stop the counter wheel until 155°. The mechanical knockoff operates at the same time each cycle. Thus it can be seen that, the higher the figure to be added, the sooner the counter clutch should be engaged to start the counter wheel turning since it will be stopped mechanically at 155° (Figure 172). If the start magnet becomes energized at 37°, the counter wheel starts rotating 13° later or at 50°. At 155° the counter wheel is stopped by the mechanical knockoff. Thus 155° − 50° = 105° of rotation of the counter wheel; 105° ÷ 15 = 7 which means the counter wheel turned 7 cycle points and added 7 in the counter. In other words, if the start magnet is energized at 37°, a 7 will be added in the counter. The timing chart shows that 37° corresponds to the impulse for a 7.

As mentioned previously, this machine has two adding cycles within one machine cycle. The preceding explanation described the direct entry type of adding where the impulses to the start magnet came directly from the card brushes. The type wheel entry cycle is identical mechanically to the direct entry type. The difference in the two types is in the timing conditions. The start magnet on a type wheel entry cycle receives its impulses 150° later than it would on a direct entry cycle. Consequently the mechanical knockoff for the type wheel entry cycle is effective 150° later than for the direct entry cycle or at 305° (Figure 173).

The type wheel impulses sometimes referred to as echo impulses) are impulses coming from the print unit.

The preceding section has to do with the general operation of the counter when adding. The next section is to show *how* the counter does the adding.

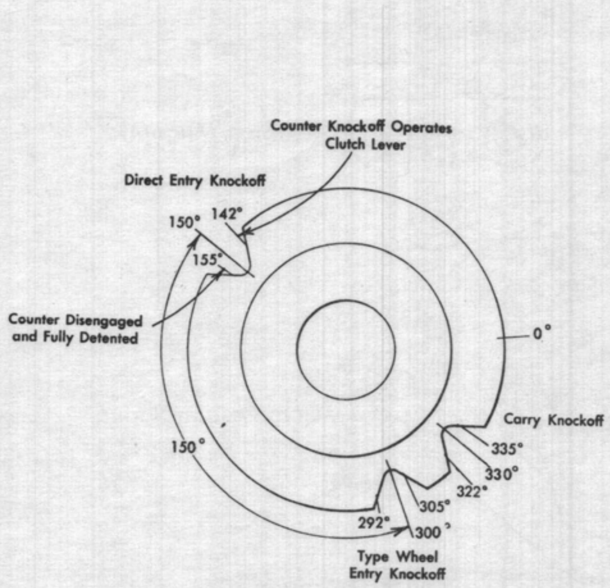


Figure 173. Counter Knockoff Cam

MECHANICAL OPERATION WHEN ADDING

A common armature operates between the start and stop magnets to actuate the clutch lever. This armature may rest in either of two positions—against the start magnet yoke or against the stop magnet yoke. When the armature is against the stop magnet yoke, the clutch disc with 10 teeth is latched on the clutch lever. When the clutch disc is latched on the clutch lever, the clutch pawl is held clear of the ratchet (Figure 174) with the result that the counter wheel assembly remains stationary. The ratchet and ratchet gear are continuously turning since the ratchet gear assembly is meshed with the counter drive gear and revolves when the counter drive gear shaft turns. However, this has no effect on the counter wheel assembly as long as the clutch pawl is held clear of the clutch ratchet.

The clutch lever is detented at its free end to insure that the armature retains its position against either the start or stop magnet and to prevent rebound when attracted to the opposite magnet. The operating time of the magnets is less than five milliseconds.

When the armature is positioned against the start magnet, the clutch lever clears the clutch disc, which in turn allows the clutch pawl to drop down and become engaged with the clutch ratchet (Figure

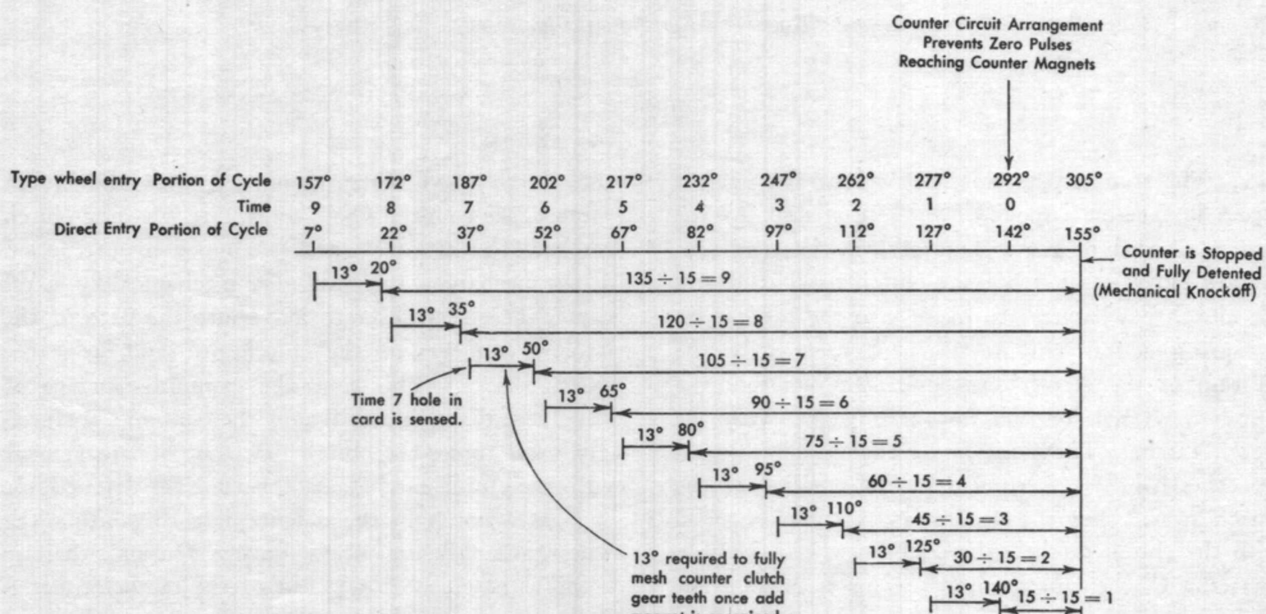


Figure 172. Counter Movement when Adding

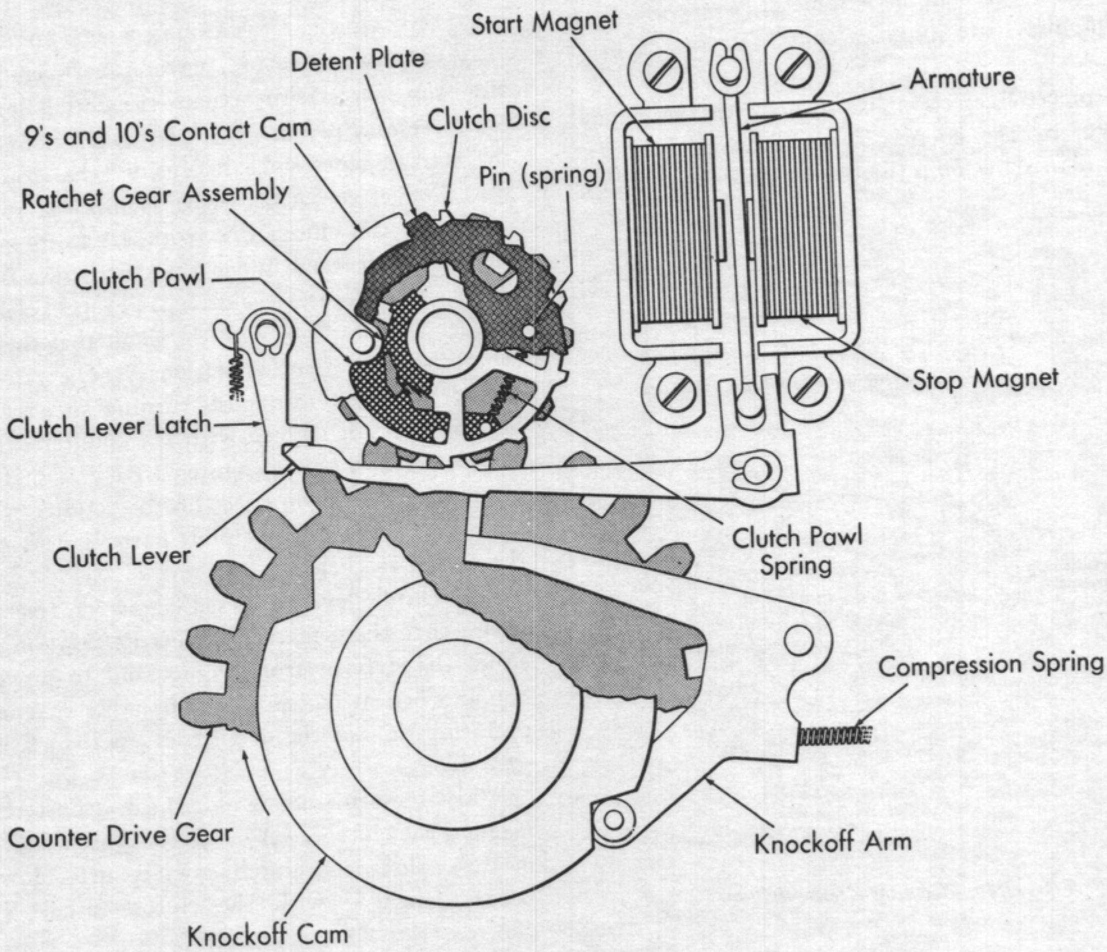


Figure 174. Clutch Pawl Disengaged

175). The stud on the clutch pawl operates against a cam surface on a spoke of the clutch disc. As the disc is allowed to move counterclockwise, the cam surface moves away from the clutch pawl stud and the clutch pawl is free to move into the ratchet by its spring action (Figure 176). Consequently the position of the clutch disc determines whether the clutch pawl will or will not be engaged with the clutch ratchet. The position of the clutch disc on the other hand is determined by the position of the clutch lever. When the clutch pawl becomes engaged with the clutch ratchet, the counter wheel assembly rotates with the clutch ratchet. This is because the clutch pawl is fastened at its pivot to the detent plate and, thus, to the counter wheel assembly. As long as the clutch pawl remains engaged with the clutch ratchet, the counter wheel will rotate with the clutch ratchet. The counter wheel is stopped by the action of the mechanical knockoff. The mechanical knockoff causes the clutch lever to move into the path of the latching surfaces of the clutch disc and stops the clutch disc. At this time the camming surface of the clutch disc operates against the stud on the clutch pawl and forces the clutch pawl out of engagement with the clutch ratchet. At this time the detent lever engages a notch in the detent plate to position the wheel assembly by heavy spring tension, thereby holding the clutch pawl clear of the ratchet teeth as the gear and ratchet assembly continues to rotate (Figure 177).

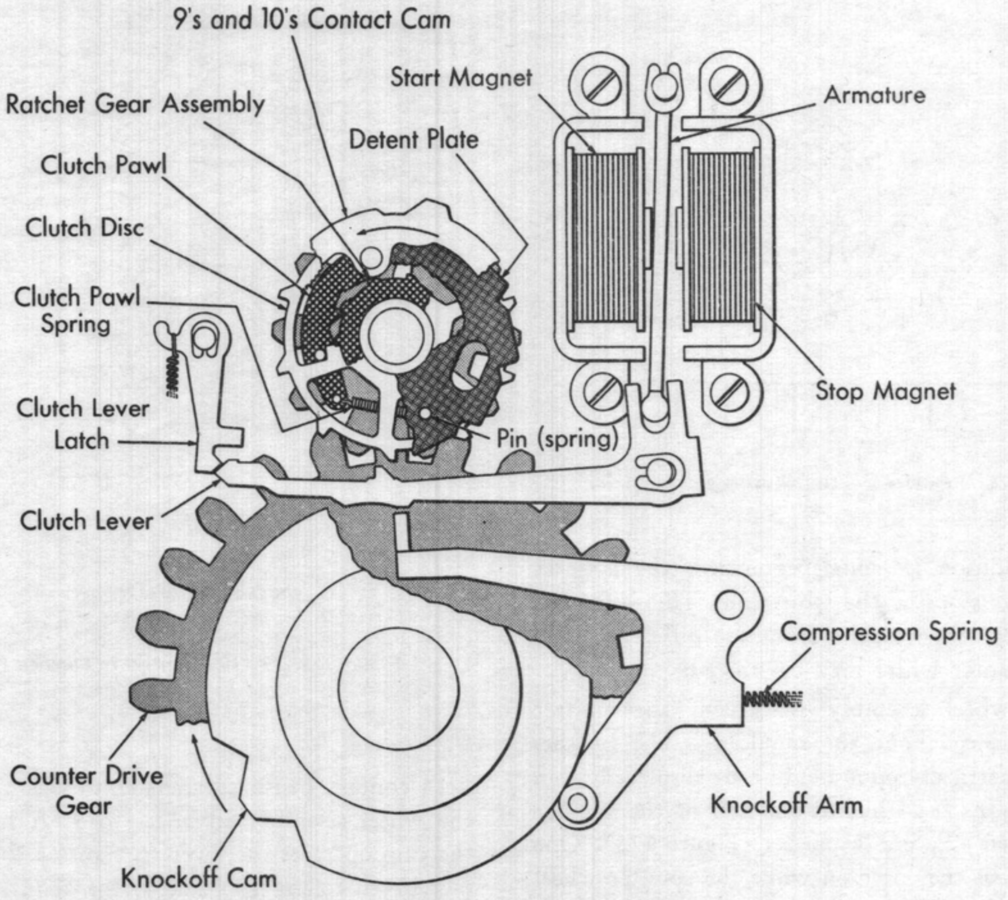


Figure 175. Clutch Pawl Engaged

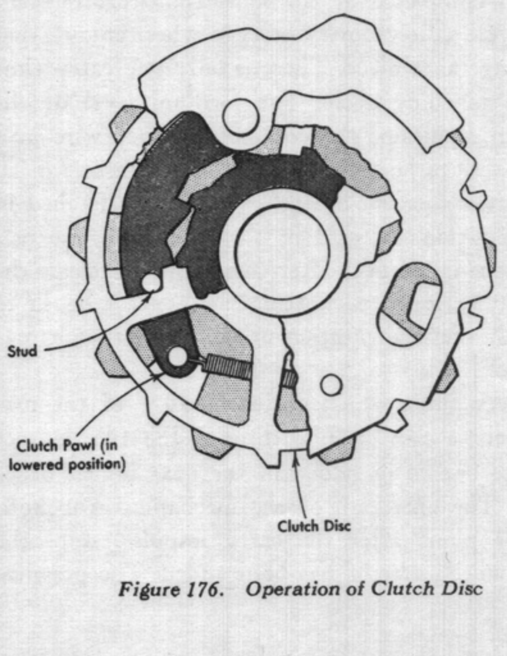


Figure 176. Operation of Clutch Disc

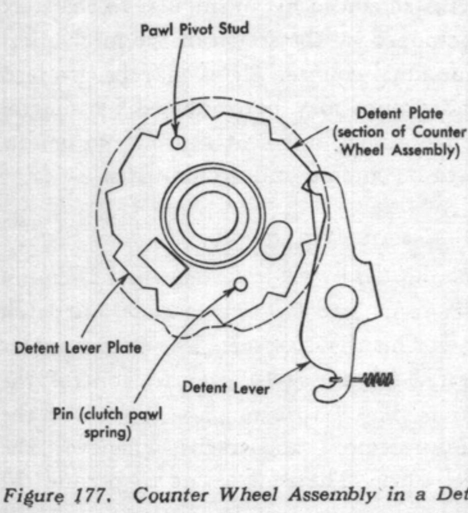


Figure 177. Counter Wheel Assembly in a Detented Position

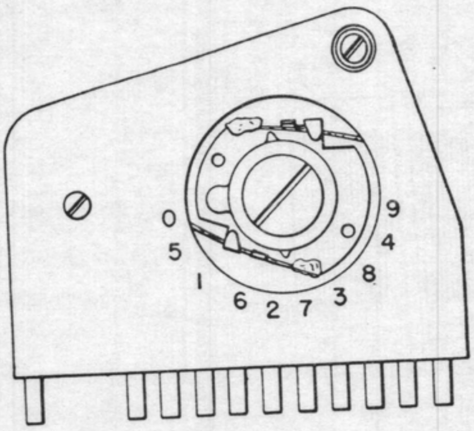


Figure 178. Counter Emitter Brushes and Moulding

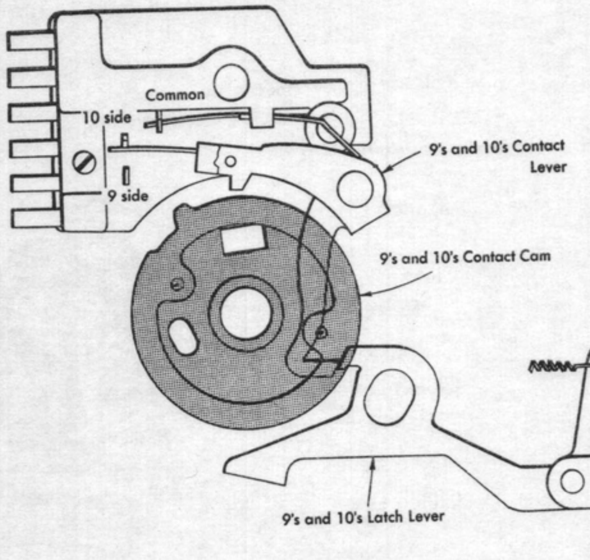


Figure 179. 9's-10's Contact in Latched Position

When addition is being performed, the counter wheel always stops at the same time. The difference in the values added results from the different times that the counter wheel may be started.

As the wheel assembly is driven, the emitter brushes advance about the moulding. The brushes are not diametrically opposite, but are displaced from this position by 18° which is one-half of the angular space between adjacent segments (Figure 178). One brush serves as the common while the counter wheel assembly moves from 0 to 4 with the second brush contacting these segments; the second brush becomes the common for digits 5 through 9 with the first brush contacting these segments.

Addition of one number to another is accomplished by advancing the wheel assembly the number of positions required by the impulse timing, regardless of the value in the counter at the time. The counter wheel is advanced by an impulse to the start magnet. It is stopped by the action of the mechanical knockoff. Individual counter plates may be grouped by wiring and groups may be combined by control panel wiring to provide sufficient capacity to handle the amounts to be entered and accumulated.

COUNTER CARRY

A carry is indicated by the counter wheel assembly when it passes from 9 to 0 (10) to close and latch the 9-10 contact on the 10's side. The 9-10 contact lever is operated by the 9-10 cam to control the contact position. The 9-10 cam plate is part of the counter wheel assembly and turns whenever the counter wheel turns. The cam is cut to permit the 9-10 contact brush to transfer to the 9's side when the wheel assembly advances to 9. A high lobe on the cam operates the lever to transfer the 9-10 contact brush to the 10's side as the counter wheel advances from 9 to 0 (10). The lower end of the contact lever latches on a latch lever to keep the 10 contact closed through carry time of the machine cycle (Figure 179). Carry time comes after all adding has been completed for the machine cycle. The carry circuit is completed at the same time regardless of which cycle (direct entry or type wheel entry) that the adding takes place. There is only one carry time for each machine cycle. The medium level of the 9-10 cam maintains the common contact wire in a neutral position between the 9-10 contacts for all digit positions except 9, and except when latched in the 10 position. A stud in the counter drive gear operates the latch lever after carry time to release the 9-10 contact lever, permitting the contact brush to assume the neutral position at the end of each machine cycle.

At carry time, which occurs at 307° of the machine cycle, a cam impulse through the 10's contact will cause one to be added in the next higher order position. The operation of the mechanical knockoff, one cycle point after the carry impulse, stops the counter wheels after 1 has been added. The presence of a 9 in a counter to the left, adjacent to one which has advanced from 9 to 0 during adding time, will extend the carry impulse to the next higher order position through the circuit arrangement. This circuit exists to all adjacent positions with 9's in the counter until it is broken by the absence of a 9 in a counter.

SUBTRACTION

Subtraction is the operation in which the value of a counter is reduced by the amount that is subtracted. If the counter wheel could be turned backwards, subtraction could be performed in this manner. Since the counter wheels cannot be turned backwards, however, some other means must be used. Subtraction is done by adding the complement of the figure to be subtracted. The following example shows that subtracting one number from a given number will give the same result as adding the complement of the number to be subtracted from the same given number: Subtract 14321 from 37834.

$$\begin{array}{r} 37834 \\ -14321 \\ \hline 23513 \end{array} \qquad \begin{array}{r} 999999 \\ 014321 \\ \hline 985678 \end{array}$$

complement of number to be subtracted

$$\begin{array}{r} 37834 \\ +985678 \\ \hline 023512 \\ +1 \\ \hline 23513 \end{array}$$

9's complement of number to be subtracted

carry-back

This machine operates on a 9 complement basis. The 9's complement of a figure is the difference between the figure and nine. Thus subtraction is accomplished by adding the difference between nine and the figure punched in the card.

To	subtract	9,	add a	0
"	"	8,	" "	1
"	"	7,	" "	2
"	"	6,	" "	3
"	"	5,	" "	4
"	"	4,	" "	5
"	"	3,	" "	6
"	"	2,	" "	7
"	"	1,	" "	8
"	"	0,	" "	9

In subtraction, the electrical circuits operate differently from those for adding, in that a fixed impulse is completed to all counter start magnets to start the counter wheels turning with a "hot 9" as the card starts under the second reading brushes. At the time the second reading brush senses the hole in the card, a circuit is completed to the stop magnet. This stops the counter wheel. The sole purpose of the stop magnet is to stop the counter wheel from turning. Under this arrangement the counter wheel does not move the distance corresponding to the distance from the hole in the card to zero, as in adding, but the distance from the 9 position of the card to the hole in the card that caused the counter wheel to be stopped. For example, if a 6 is punched in the card, the counter wheel starts turning at 9 time and stops at 6 time; therefore, the counter wheel turns for 3 cycle points. The 9's complement of 6 is 3, consequently the complement of the figure to be subtracted is added.

When subtracting, all counter positions start turning at the same time but stop at different times, depending upon when the stop magnet is energized by sensing a hole in the card. Adding, on the other hand, is just the opposite. When adding, the counter wheels start turning at different times, depending on when the start magnet is energized by sensing a hole in the card, but all counter wheels stop at the same time by action of the mechanical knockoff.

The impulse to start the counter wheels turning when subtracting is called a "hot 9" since the impulse comes through automatically when a card is being subtracted at the same time that a 9 would be read from a hole in the card. If a 9 is to be subtracted, the start magnet receives the "hot 9" impulse for subtracting at the same time that the stop magnet receives its impulse from the 9 hole in the card. Consequently, the counter wheel should not move. As noted previously, to subtract 9, zero is added, therefore the counter wheel should not move. See Figure 180 for the duration of the cycle on which the counter wheel turns while subtracting various amounts.

MECHANICAL OPERATION WHEN SUBTRACTING

The mechanical operation of the counter when subtracting is quite similar to that when adding. The main difference is in the method of stopping the counter wheels from turning. In adding, the mechanical knockoff stops the counter wheel; in subtracting, the energization of the stop magnet causes the counter wheel to be stopped.

During a subtraction cycle the start magnet becomes energized at 7° by a "hot 9" impulse. As

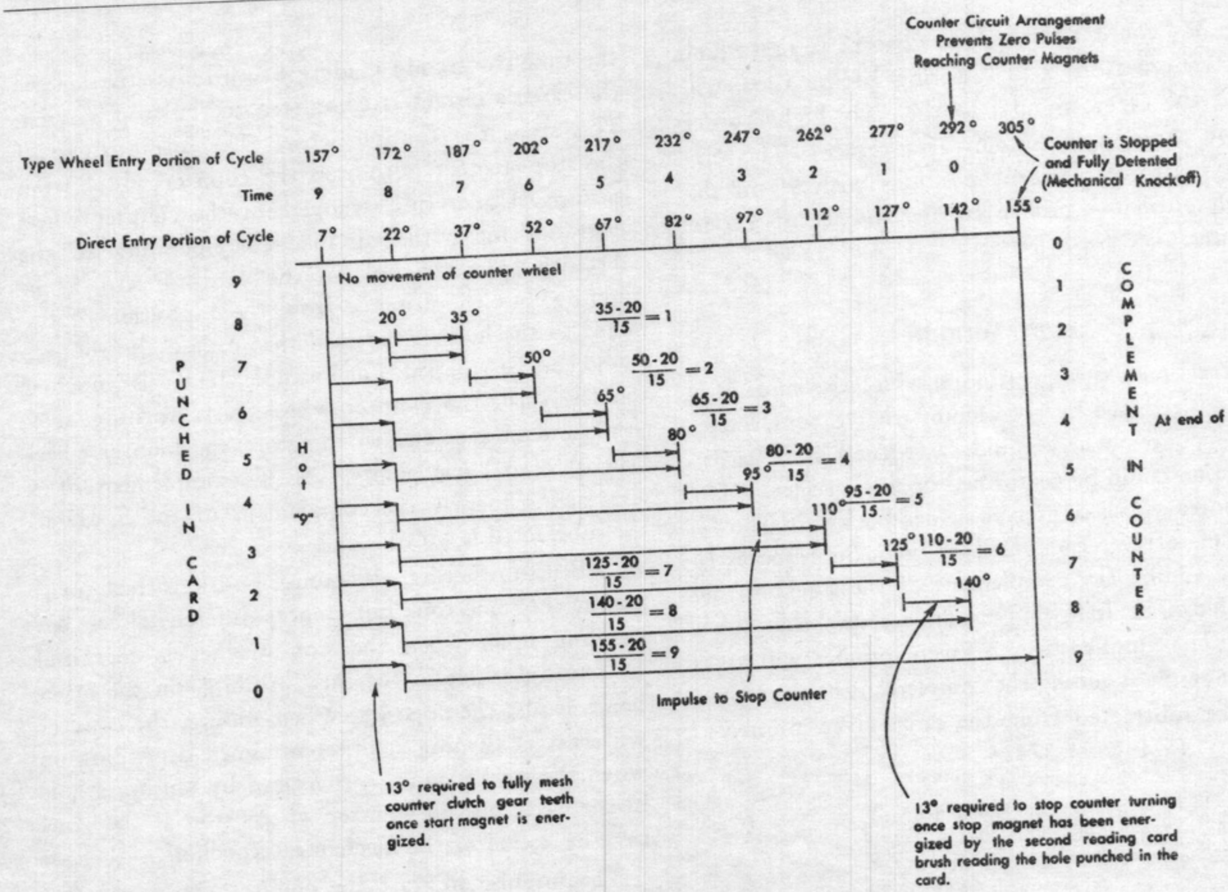


Figure 180. Counter Movement when Subtracting

when adding, this causes the clutch lever to move free of the clutch disc, which in turn allows the clutch pawl to drop into the clutch ratchet (Figure 175). All counter positions of the counter groups being subtracted receive this "hot 9" impulse and, unless a 9 is to be subtracted, all counter wheels will start turning at the same time. At the time the hole in the card is sensed, a circuit to the stop magnet, corresponding to the position read, is completed and causes the magnet armature to be attracted to the stop magnet core. The operation of the magnet armature to the stop magnet side causes the clutch lever to pivot and move into the path of the latching surfaces of the clutch disc. As the clutch disc comes up against the clutch lever, the clutch disc is stopped. The counter wheel assembly tends to continue to rotate but, as it does, the clutch pawl operates against the cam surface on the spoke of the clutch disc and rises out of the clutch ratchet; this causes the entire counter wheel assembly to stop. The detent lever operates so that the counter wheel assembly is in the proper position to keep the clutch pawl free of the ratchet and the emitter brushes positioned on the proper segment.

Figure 181 shows the timing relationships for adding and subtracting with both direct and type wheel entry impulses.

It should be noted that the advance of the clutch disc, as it is released by the clutch lever and pulled by the clutch pawl spring, insures that at least "1"

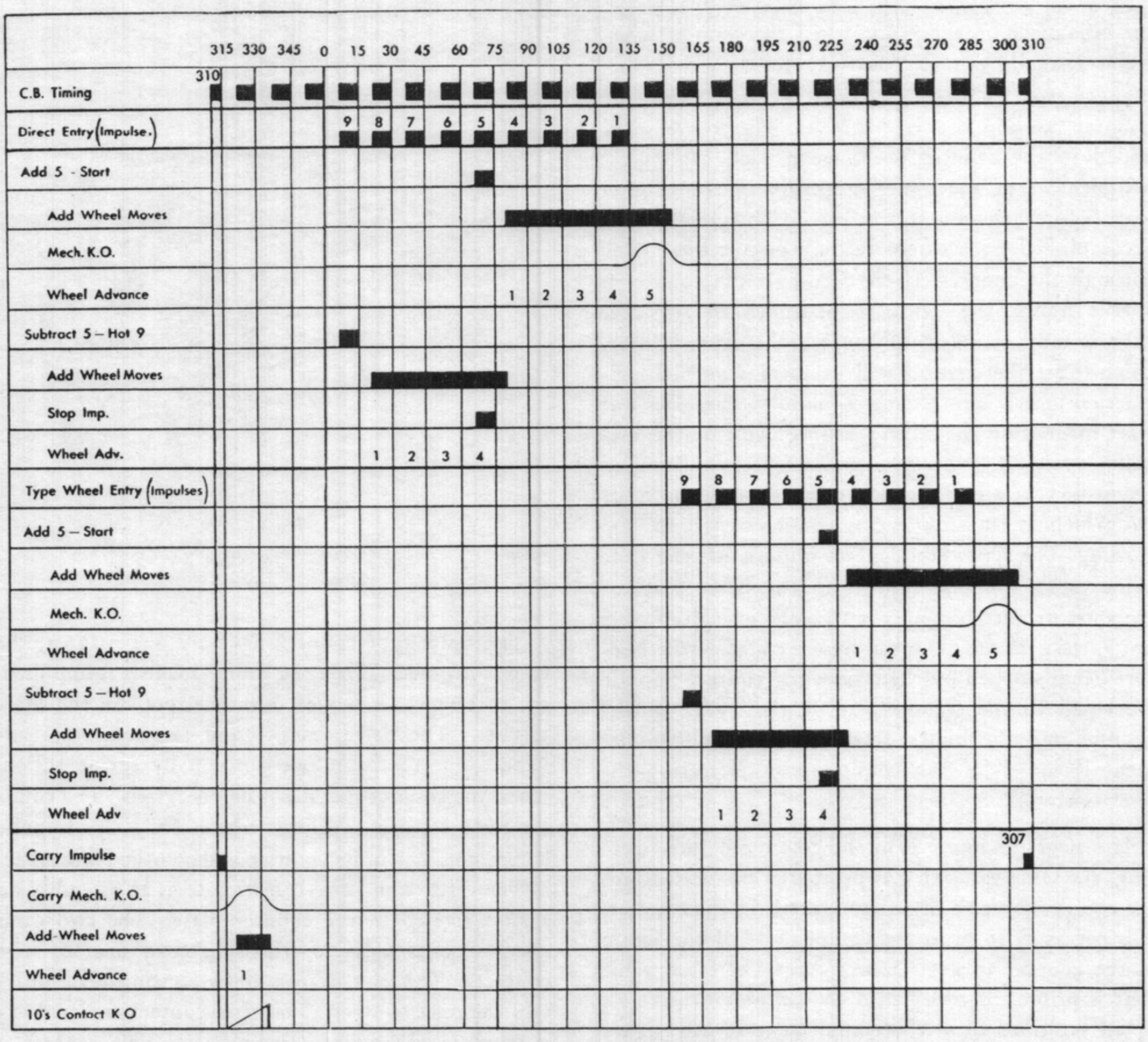


Figure 181. Timing Chart — Direct Entry and Type Wheel Entry Impulses

will be added to the counter as the result of this release. A simultaneous impulse to both magnets will not cause any armature movement because of the magnetic cancellation of the coils and detenting of the clutch lever. The armature will remain against the magnet as positioned before the simultaneous impulses are received. This condition occurs when a 9 is being subtracted on a complement basis. To prevent tripping the counter clutch, therefore, it is of extreme importance that the automatic hot 9 impulse to the start magnet and the 9 impulse from the card occur simultaneously.

COUNTER RESET

The counters are reset by adding values in each counter position that will cause the counters to have a 9 standing in each position at the end of the reset cycle. When the counter has a zero value, all the counter wheels are standing at 9. This provides a means of checking for a zero balance since the 9-10 brush is made on the 9 side when the counter wheel has a 9 standing in it. Checking for a zero balance is done after each reset cycle to ascertain that each counter position is correctly reset. The figure to be added to the counter positions in each case is the complement of the figure originally in the counter just before resetting takes place. This resetting is accomplished by a direct reading circuit established through the counter. If the figure in the counter is a true figure, the figure to be added to reset the counter must be the complement of the figure printed. In this case the counter will perform a normal subtraction operation. A hot 9 impulse energizes the start magnet on the second adding cycle of the machine cycle. A typewheel contact impulse coming from the type wheel contacts energizes the stop magnet which in turn causes the counter wheel to stop turning. The typewheel contact impulse has the same value as the impulse read from the counter. Since the start magnet had previously been energized by a hot 9, the cycle points taken by the counter wheel before being stopped by the type wheel contact impulse are equal to the complement of the figure in the counter and the figure printed. Thus, the complement is added to each counter position during the reset operation.

If a negative figure is in the counter before resetting, the same value that is printed is also added into the counter. Since a negative figure is in the counter, it is necessary to print the complement of the figure in the counter to get a true figure. The same value that is printed is added into the counter to give 9's in all positions since the complement of the figure in the counter is added to the original figure.

UNIT TYPE COUNTER

THE UNIT type counter used in the Type 101 Electronic Statistical Machine is a mechanical counter, controlled electrically. There is no need for any external mechanical drive for operating the counter. Each counter is a self-contained unit that only requires electrical connections. The counters are inserted into terminal mouldings. Electrical connections are made by means of contact springs anchored in the terminal mouldings. No timing of the counters is necessary and no external wiring is required.

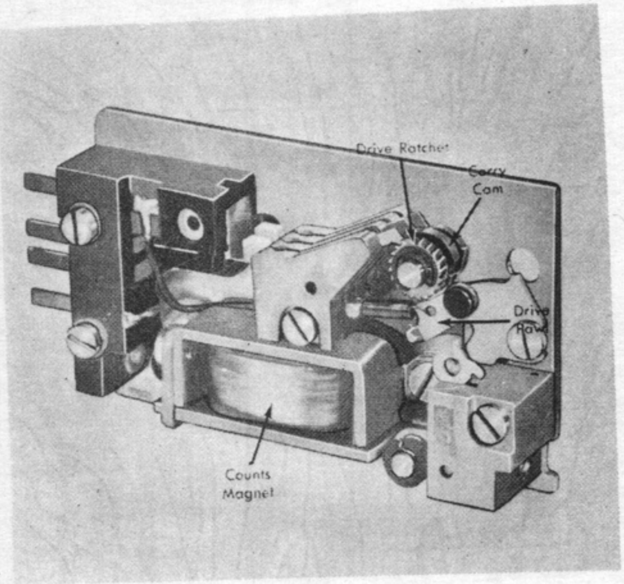


Figure 182. Units Counter

The units type counter has only one magnet, the counts magnet. When the counts magnet is impulsed, the drive pawl is moved over one tooth in the drive ratchet. The drive ratchet and two cams are advanced one tooth, or one position by spring action, when the counter magnet is de-energized. The counter advances one position, or unit, for every impulse it receives. The units counter is shown in Figure 182.

The ratchet and two cams rotate as an assembly on a stud riveted to the counter plate. The two cams operate contact levers which in turn operate wire contacts. The cam nearest the mounting plate operates the reset contact. The reset contact is closed except when the counter is at zero. This contact is used when resetting the counter; a series of impulses is sent to the counter through the reset contact. The reset contact is opened when the counter is advanced to zero; as a result no more impulses can reach the counts magnet.

The second cam from the mounting plate is the carry cam. This contact is opened except when the counter is at nine. This contact is used for carry into the next higher order counter and for printing.

The carry contact recognizes when the counter contains a nine, and as a result of the next impulse received, a carry is accomplished. The carry contact directs the impulse on to the next higher order position and if this position also contains a nine, the impulse will be extended to the third position, etc.

The read out of this counter occurs during a reset cycle. The carry cam permits the carry contact to make when the counter reaches the nine position. The next impulse causes the counter to advance to zero, but, at the same time, the impulse is allowed to pass through the carry contact to print.

IBM uses several counters which operate on the principle of adding a single unit for every impulse received; the other types use an emitter to read out, and can read out without resetting.

VACUUM TUBE COUNTER

A VACUUM tube counter is used in the Type 604 Electronic Calculating Punch. The electronic counter works on the principle that a vacuum tube circuit can be arranged to have two definite states. If the control grid of a vacuum triode is at cathode potential, the tube conducts. If the grid is made very negative, the tube is cut off. Two triodes are combined in an electronic circuit called a *trigger;* these tubes control each other so one conducts when the other is cut off, and vice versa. This electronic circuit is analogous to a toggle switch in that it can stay in either of two conditions. Each electrical impulse causes the triggers to change states. Triggers are the building blocks of which the electronic counter is composed.

Number Systems

Some background of numbering systems is desirable for a better understanding of an electronic counter. The decimal system in common use is based on the number ten. It is very likely that this system originated because there are ten fingers on the two hands. However, there are systems based upon other numbers in limited use today; for example, counting by dozens, etc.

A system can be developed using any number as a base, and a knowledge of only a few fundamentals is necessary to do this. The decimal system begins with zero, as all systems must, and as we count, it progresses to nine and returns to zero while a one is carried into the second position. If a system of numbers is to be developed on a base 5, it would begin with zero and progress to 4, then return to zero and carry a 1 into the second position. The following table shows a comparison of a base 10 system, a base 5 system and a base 2 system.

Base 10	Base 5	Base 2
0	0	0
1	1	1
2	2	10
3	3	11
4	4	100
5	10	101
6	11	110
7	12	111
8	13	1000
9	14	1001
10	20	1010
11	21	1011
12	22	1100
13	23	1101
14	24	1110
15	30	1111
16	31	10000

This table could be carried as far as desired; however it has been extended far enough to show the principles.

Observe that the system of numbers on the base 2 begins with a zero and advances to one when one unit is added. When a second unit is added, the first position returns to zero and carries into the second position. This process is continued until any desired number is reached.

The important fact to note about a number system based on 2 is that there are actually only two numbers involved, zero and one; the name *binary* system is given to the base 2 system for this reason. All positions in the number must contain either a zero or a one. Because relays and electron tubes also have two states, they are ideal for storing binary numbers. One of the two states will represent the presence of a zero; the other will show the presence of a one. By definition, a trigger which is ON will indicate a one in that position.

The binary system can be converted to the decimal system rather readily. There is a formula which can be used to convert a number on any base to a decimal base. The binary system has a definite and recognizable pattern as the number of positions increases. The value of each position added has a value in the decimal system exactly double the decimal value of the preceding position.

A table of decimal equivalents can be made from this knowledge.

Binary Value		Decimal Equivalent
1st position	1 =	1
2nd position	10 =	2
3rd position	100 =	4
4th position	1,000 =	8
5th position	10,000 =	16
6th position	100,000 =	32
7th position	1,000,000 =	64
8th position	10,000,000 =	128
9th position	100,000,000 =	256
10th position	1,000,000,000 =	512
11th position	10,000,000,000 =	1024

The decimal value of a binary figure, such as 1001, can be found by the following procedure:

The one in the 4th position =	+8
The zero in the 3rd position =	+0
The zero in the 2nd position =	+0
The one in the 1st position =	+1
The total decimal value	9

The first table will verify these results and this method. The same method can be used regardless of the size of the number. For example, the decimal value of 110001011 is:

The one in the 9th position =	256
The one in the 8th position =	128
The one in the 4th position =	8
The one in the 2nd position =	2
The one in the 1st position =	1
The total decimal value	395

It is possible to make up entire counters using only the binary system. However, there are many advantages in being able to read directly into and out of a counter. Consequently, it is desirable to keep each position on a decimal base. Each counter position would require triggers for each of the ten possible digits if the decimal system were used. However, by modifying the binary system, only four triggers will be necessary for each counter position. Figure 183 shows how electronic triggers are used to accumulate using the binary system. If a trigger is ON (containing a one) it is represented by a white circle; a black circle represents a trigger which is OFF, representing zero.

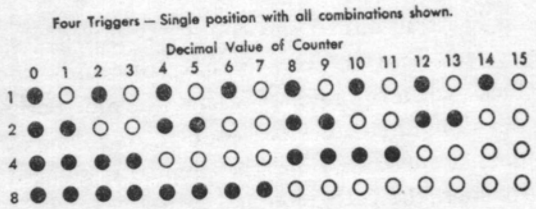


Figure 183. Schematic of Electronic Counter

Notice that the triggers follow exactly the pattern developed in the chart shown earlier. Because each counter position accumulates 9 and then goes to zero, controlling circuits beyond the scope of this book are used to stop the counter action at 9. Each impulse sent to the triggers causes the counter to increase, up to 9. The tenth impulse turns OFF all the triggers in that counter position and causes an impulse to be sent to the next higher position. The next position will accumulate one as a result.

It is evident that the counting capacity of a position is not fully utilized, but this is offset by the advantage of having the counters operate directly in decimal numbers.

To add into these counters, the information, read from a card, is sent to the individual counter position in the form of a series of impulses. For example, if a nine is sensed and is to be accumulated in position one, nine impulses will be sent to trigger one in position one. The first impulse to trigger one will turn it on, indicating one has been accumulated. The second impulse turns trigger one off and turns trigger two on, indicating two has been accumulated. The third impulse turns trigger one on again and trigger two is still on, indicating a three. The fourth impulse turns triggers one and two off and turns trigger three on, indicating a four. The counter continues to accumulate using the binary system until a nine is indicated as a result of the nine impulses directed to trigger one. The next impulse received by trigger one will turn off all of the triggers in that position and carry a one into the next higher position.

PRINTING MECHANISMS

PRINTING is one of the most important functions of IBM Data Processing Machines. It is through the medium of printing that the finished products of the Data Processing Method of Accounting are produced. These products are printed reports and document forms which are required by the customer for the efficient operation of his business. He is vitally interested in the quality and legibility of the printing on these forms because many of them, such as statements, invoices and shipping notices are placed in the hands of his own customers.

The Data Processing Machines provide the quality and legibility desired. There are many factors which contribute to satisfactory printing results. A number of these are listed below:

1. Paper — its texture and ability to receive the inked type impression clearly and sharply.
2. Ribbon — affects the clearness of printing.
3. Carbon paper — determines legibility of carbon copies and is particularly important when numerous copies are required.
4. Impression — affects the quality and legibility of the printed character. Impression is affected by the impact or pressure of the type against the paper, and also by the hardness of the platen.

In addition to the above, an important factor is the design and type of the printing mechanism. It is with this principle that this chapter will deal primarily.

Printing Systems

Books, magazines and newspapers are commonly produced by letterpress printing, in which the ink is carried by the raised portions of type. Similarly, typewriters and accounting machines produce their results by pressure from the raised surfaces of type. In the printing of books, the individual type pieces required to make up each page are usually set up in a form. These forms are placed in a printing press which produces the desired quantity of printed pages. In the adaptation of printing to typewriters, adding machines, desk calculators, electric accounting machines, etc., the methods differ because the setup changes with each printing operation. A selecting mechanism is provided to select the individual type characters which are to be printed. To accomplish this, two distinct systems are employed; serial and parallel printing.

Serial Printing

The typewriter is an example of the serial printing system. The characters are individually selected and printed one character at a time, on the printing line. Immediately following the printing of each character, the paper is moved to the left by a carriage, positioning the paper to receive the printing of the next character.

Parallel Printing

This method of printing is used generally on desk calculators, adding machines and IBM Data Processing Machines. The mechanism used consists of groups or banks of type bars, wheels or sectors, in parallel arrangement. Each of these carries a full complement of numerical characters, or numerical and alphabetical characters. During the selection or setup portion of the operation, the desired character in each type bar or wheel is selected and positioned at the printing line. At a definite time later in the cycle of operation all of the type characters are pressed against the paper simultaneously. Thus an entire line is printed at the